Australian ITER Forum

A strategy for

Australian fusion science and engineering

Through ITER and into the future

August 2007

http://www.ainse.edu.au/fusion.html

Contents

Preface

Strategy objective

To enable Australians to benefit from global developments in fusion science, through the development of knowledge, skills, business opportunities and linkages.

The current debate on the world's future energy requirements and the need to reduce carbon dioxide emissions has focussed the community at large and government leaders on the need to develop alternative baseload power sources.

Strong progress has been made over the decades towards viable energy production using fusion. ITER marks the next step. The research outcomes of ITER will be used to guide design of DEMO, a prototype power plant. It is envisaged that fusion will become a commercial technology in the second half of this century.

ITER will be built at Cadarache in southern France, and is due to start operation in 2016. The estimated cost of the ITER project is five billion euro (more than A$8 billion) over 10 years, and another five billion euros are foreseen for the 20-year operation period.

Such large programs are now intrinsically international. The seven parties to the ITER implementing agreement are the European Union (EU), Japan, the People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA. ITER is also a flagship project of the International Atomic Energy Agency (IAEA).

The Australian ITER Forum was formed in 2004 by Australian researchers at the leading edge of this field, with the primary objective of fostering engagement by Australians in the ITER project. The Forum built on a long history of Australian achievements in research related to fusion energy.

It successfully applied for an Australian Government International Science Linkages (ISL) grant to hold a workshop for international participants in the ITER project and Australian researchers, representatives of Australian industry and government. The workshop, held in October 2006, attracted about 80 participants, including delegates from the EU, China, the USA, India and Japan. It was opened by the Australian Government Chief Scientist, Dr Jim Peacock.

Delegates to the workshop agreed that Australia could add value to ITER and that this would benefit the Australian scientific and broader communities. They agreed that a strategy was needed to move forward. This was reiterated in discussions with key Australian Government officials and international delegates.

The development of the strategy began with the publication of an issues paper in December 2006, which set out the situation of fusion-related research in Australia and options for going forward. Responses to that paper, presentations and discussion at the international workshop and discussions within the Australian research community and Government form the foundation of this strategy plan.

The plan looks forward over the coming decade. While it began with a focus on Australian engagement in ITER, there is strong support for a broader strategy related to fusion energy, which is reflected in this plan.

Executive Summary

An increased Australian investment in fusion-related research, development and education offers multiple potential benefits, including realising the revolutionary prospect of energy from fusion; additional options for Australia's energy security; wider technology spinoffs; and business opportunities from Australian intellectual property. In addition, fusion research can play a role in attracting students to science, engineering and technologies studies.

This is a timely and opportune plan. It addresses growing community concerns about climate change and capitalises on the imminent construction of ITER – an experimental fusion device that sets the path for fusion energy development over coming decades – as well as calls to increase Australian participation in mega-science programs.

Fusion is the process that powers the stars. Australians pioneered fusion research, and the nation today has world-class expertise in stellarator physics, plasma diagnostics, fusion theory, plasma-surface interactions and materials research. However, while other major economically developed countries are expanding their investment in fusion-related fields, Australia's capabilities are static and dispersed. It is time to form new generations of researchers with expertise in this area, looking towards the future when commercially viable fusion power plants are being built.

A new "Australian Fusion Initiative" would enable the development of expertise and industry capabilities to meet the nation's long-term needs. The Initiative would comprise:

- A fellowships program, focused on early- and mid-career researchers to enable Australia to build up its base of researchers with relevant expertise
- The development of an ITER machine technology contribution – a diagnostic instrument – which would serve as a flagship for Australia's national effort in this area and deliver defined benefits to the nation
- Support for research infrastructure, both to enable the development of an ITER diagnostic and to invest in new facilities and operation of facilities, established on a leveraged basis
- Support for travel and exchanges.

The Initiative would also coordinate international linkages and support outreach. Any institution would be able to participate in the Initiative, which would embed Australian efforts in international programs.

The Australian fusion-related science and engineering community is seeking government funding for this Initiative, which would be complemented by use of existing schemes. The level of funding being sought is approximately $60 million over 10 years.

An important issue is how best to manage international engagement towards an Australian ITER machine contribution. Direct engagement with the ITER Organisation would provide the most direct linkages with the ITER project. It would provide high-visibility greater autonomy and a mechanism to capture long-term spillover benefits through wider collaborations, student exchanges and commercial opportunities.

An alternative would be engagement with an ITER partner. (The partners are the European Union, Japan, the Russian Federation, the USA, China, the Republic of Korea and India.)

Strategic partnerships, certain international agreements and forums, and an international network of researchers, are other promising ways to leverage a contribution to fusion science in selected research areas.

1. The opportunity

1.1 The revolutionary prospect of energy from fusion

"Why should Australia increase its investment in fusion-related R&D and education?"

Australia's current investment in fusion-related research, development and education (RD&E) will not be enough to meet its future needs, and Australians can make a real contribution to bring about the introduction of electricity from fusion reactions.

The fusion of certain elements releases enormous amounts of energy, at levels needed for baseload power but without emissions of carbon that are contributing to climate change (see Appendix 1 for a description of how fusion works). It would enable nations to reduce their reliance on fossil fuels, such as coal, gas and oil, and uranium-based power reactors, which use the principle of nuclear fission.

Climate change is an issue of fundamental significance to the long-term sustainability of our planet. An increased investment in fusion-related RD&E would demonstrate a long-term response to the Australian community's concerns about the way energy generation is contributing to climate change. It would also enhance the nation's reputation internationally for action on climate change, and science and technology generally.

Such a source of electricity would be ideal for desalination, as it would not have the problems of current systems that add to carbon emissions through the electricity that they use.

These technologies therefore address the National Research Priority Goals of Water – a Critical Resource (NRP 1.1) and Reducing and Capturing Emissions in Transport and Energy Generation (NRP 1.4).[1]

The potential economic return from fusion energy is enormous. A recent US study concluded that although the cost of developing fusion as an energy source is approximately US$80 billion (2005 dollars), the present value of the energy produced from fusion over a projected 2050-2150 deployment timeframe ranges from US$11 trillion to US$120 trillion, which is 140 to 1500 times greater. In this model, fusion power ramps from 0% of total world energy production in 2050, to approximately 30% in 2150.[2]

Australia has a solid, long-standing base of scientific and engineering expertise that could contribute to the development internationally of fusion-based electricity generation systems. (See Appendix 2.)

1.2 Options for energy security

It is generally recognised that our society in the future will depend on a portfolio of sources of baseload energy (such as provided by coal) and dynamic load (such as provided by solar, hydro and other renewable energy technologies). An increased Australian investment in fusion-related RD&E will give the nation an option to take up fusion as an electricity source when commercial systems are coming to the market. If this is to be a genuine option for Australia, the nation will need people with expertise and skills in this area, to help make decisions about its potential implementation and to advise on selection of technologies. This expertise will be found in people who have high-level knowledge of the science and technology involved, solid experience and personal relationships with key world players. They will need to have background in the field and analytical ability to be able to make intelligent judgements about available options and provide independent advice to

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1 Large-scale, low-emissions energy technologies were also identified as a capability in the National Collaborative Research Infrastructure Strategy, although this capability has not been funded.

2 R. J. Goldston, D. H. Goldenberg, J. S. Goldston, L. R. Grisham, J. D. Linton, 2006, www-pub.iaea.org/MTCD/Meetings/FEC2006/se_p2-1.pdf, p6

Government (independent, that is, in terms of not being sourced from commercial interests).[3] That capability will only be attained if Australia increases its RD&E in fusion-related science and engineering.

If the option of using fusion as a commercial energy source is taken up, the nation will then need a platform of expertise for the construction and operation of such plant, and to train the next generation of experts. The absence of such skills would hamper efforts to adopt fusion power systems, just as is acknowledged to be the case in the potential adoption of nuclear power based on fission.[4]

The generation of options for the nation was a major theme of the 2006 Productivity Commission report on public support for R&D.[5] Sir Nicholas Stern in his October 2006 report, on the Economics of Climate Change, stated that, "The uncertainty and risks inherent in developing low-emission technologies are ideally suited to a portfolio approach." [6]

Regardless of whether the fusion option is eventually adopted, investment in this area will support other parts of the nation's energy options portfolio. A significant proportion of the knowledge and skills needed for fusion energy systems is also relevant to fission energy and high-temperature steam energy plants. This will be particularly relevant to Australia's involvement in developing the next generation of fission energy systems (Generation IV).[7] Participation in fusion research would strengthen the international linkages related to nuclear power, most notably with the International Atomic Energy Agency, and the OECD's Nuclear Energy Agency (NEA) and International Energy Agency (IEA)[8].

1.3 Spillover and Spinoffs

Fusion reactors will require the development of new materials due principally to the extremely high flux of neutrons and the localised high heat flux on the divertor tiles, but also to protect the superstructure from any transient disruptions of superheated plasma and any charged energetic particles that lose confinement. These materials are expected to be used in other forms of energy generation as well, including nuclear power reactors, high-temperature coal-fired power generation systems, geothermal energy and solar thermal. Future nuclear power reactors are likely to use similar materials to fusion reactors as they will have higher energy neutrons.

Applications of these materials will spill over from the energy sector to wider areas of industry. These materials will be wear-resistant and able to bear high heat and radiation loads, which will be highly attractive to industry. Materials developed for the extreme conditions imposed by a fusion plasma will also be relevant to other industries that work with extreme conditions, such as the aerospace and mining industries.

The extraordinary remote-sensing measurement challenges posed by fusion plasma give powerful impetus to innovations, new technologies and methods that are finding application

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3 A comparison is the way that the Australian Nuclear Science and Technology Organisation (ANSTO) is able to meet the Government's need for advice on fission energy, although it has not been directly undertaking research in nuclear power for decades.

4 Commonwealth of Australia 2006, Uranium Mining, Processing and Nuclear Energy — Opportunities for Australia?, Report to the Prime Minister by the Uranium Mining, Processing and Nuclear Energy Review Taskforce, December 2006, (Switkowski Report), www.dpmc.gov.au/umpner/reports.cfm#full, p2

5 Productivity Commission 2007, Public Support for Science and Innovation, Research Report, Productivity Commission, Canberra, www.pc.gov.au/study/science/finalreport/science.pdf, various references including p87

6 Stern Review on the Economics of Climate Change, www.hmtreasury.gov.uk/independent_reviews/stern_review_economics_climate_change/sternreview_index.cfm, p358

7 The Prime Minister announced on 28 April 2007 that Australia will seek to become a member of the Generation IV International Forum. See http://www.pm.gov.au/media/Release/2007/Media_Release24284.cfm

8 The IEA Fusion Power Coordinating Committee coordinates IEA activities on fusion and advises IEA bodies on fusion policy and technology issues. It has 19 members, from IEA countries, the European Commission, the Russian Federation, the NEA and the IEA.

in other areas of science and technology, as well as industry, defence and medicine. For example, plasma microwave techniques are being applied to breast cancer imaging, and advanced colour imaging technologies developed at the Australian National University (ANU) are being used to estimate iron and steel temperatures at Bluescope Steel Limited in Wollongong. The ITER diagnostic suite, which spans the spectrum from radio frequencies to gamma rays, will be the most comprehensive to date, and will likely continue to spawn new technologies with applications further afield.

A core area of fusion-related science is plasma science, which also plays an important role in astrophysics and space science. Increased RD&E in fusion science and engineering is likely, therefore, to benefit Australia's world-renowned astronomy community. Better understanding of magnetised plasma could lead to a deeper understanding of our solar system, perhaps giving a clearer picture of atmospheric and oceanic turbulence and flows, and ultimately to cheaper fusion power plants. Plasma science contributes to a range of industries, including microelectronics, lighting, hazardous waste disposal and television screens.

In addition, spillovers to information technology are anticipated, due to the data processing demands of fusion systems.

1.4 Business opportunities

An increased Australian RD&E effort in fusion-related science and engineering will require new systems and generate intellectual property (IP) with commercial benefit, especially with regard to the energy sector, innovative materials and plasma science. Innovations in energy technology have strong export potential, due to the worldwide growth in investment in this area.

The major international fusion-related projects could be vehicles for Australian businesses to showcase sophisticated Australian innovation and technology. Australians active in fusion-related RD&E will be well positioned to provide information, including contacts, to Australian businesses that have products and services of value in fusion energy, to help them become commercially involved in international developments. Collaborations with Australian researchers in this area will also increase their awareness of innovations from other countries, encouraging take-up of innovations in Australia and thereby productivity and competitiveness.

To date the Australian minerals industry does not appear to have addressed the export demand for the minerals that will be extensively used in fusion energy systems. Australia has among the largest reserves in the world for several key minerals such as vanadium, lithium, tantalum, titanium, zirconium and niobium. In coming decades these minerals will be attracting international interest for their potential use in fusion energy systems, and the Australian RD&E base will be a source of knowledge for the Australian minerals sector.

1.5 Australian science engagement

The development of fusion energy has been an international cooperative effort since the 1950s. This is exemplified in the ITER project, which is being developed by seven parties, namely the EU, Japan, the People's Republic of China, India, the Republic of Korea, the Russian Federation and the USA.

A number of recent reports have emphasised the benefits of increased Australian engagement in major international science activities. A recent report by a working group of the Prime Minister's Science, Engineering and Innovation Council (PMSEIC) on global science engagement identified the need for a strategic national approach.[9] There are a

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9 PMSEIC Working Group on Australia's Science and Technology Priorities for Global Engagement, Report, Canberra, December 2006, www.dest.gov.au/sectors/science_innovation/publications_ resources/profiles/presentation_global_engagement.htm, p12

number of reasons for taking such an approach in fusion-related science and engineering in particular.

1. Perhaps the most important reason is that Australian engagement in this area will enable Australians to be fully up-to-date with developments internationally, and to take advantage of the substantial investments that other countries are making in fusion-related science and engineering. Experimentation on ITER will generate massive quantities of data, but access to that data will be restricted. Australian involvement should be used, in part, to gain data access (see Section 5.1).
2. Australia has a prestigious position in fusion science, which goes back to its very discovery by an Australian, Sir Mark Oliphant, in 1933 (see Appendix 2). Australia has an especially strong reputation in plasma physics. However, without an increased investment in fusion-related RD&E, this reputation is likely to fade.
3. Fusion-related research falls within the areas of national strengths identified by the PMSEIC working group, namely energy resources and technology, and materials science.[10]
4. The PMSIEC Report recognised the importance of "a broad and energetic fundamental science base that is encouraged to work on tomorrow's projects". The ITER project is unquestionably one of the most important of "tomorrow's projects" which is a reason for using fusion-related science and engineering as a prong in Australia's global science engagement. Its budget makes it one of the largest science projects of the coming decade.
5. Australian engagement will also further the nation's relationships in related areas, most notably nuclear fission technologies and materials, as discussed above. The Switkowski Report highlighted the strong relationship between global engagement and local capability development, and noted the links between fission and fusion energy.

The House of Representatives Industry and Resources Committee, in its *Australia's uranium — Greenhouse friendly fuel for an energy hungry world* report, was persuaded of the immense potential benefit that fusion energy represents for the world and, specifically, the potential benefits for Australian science and industry from involvement in the ITER project. The Committee believes "that involvement in this experimentation is simply too important for the nation to miss."[11]

1.6 Boost for science and engineering education

There is a clear need for more Australian scientists and engineers. Australia's involvement in fusion energy, especially the iconic ITER project, could be promoted as an exciting, huge science experiment, to encourage Australian students to take up the study of science and engineering. It will capture student interest as a new technology addressing climate change, calling for demanding physical conditions and offering opportunities to work overseas.

1.7 Urgency of action

The development of fusion energy is entering a major new phase, with the construction of the ITER device now commencing and due to be completed in 2016. Its design and the experiments conducted on it will define the path of fusion energy development over the next 30 to 40 years.

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[10] ibid, p20

[11] Prosser Report, tabled on 4 December 2006. In Recommendation 14, the Committee recommended that Australia secure formal involvement in the ITER project.

Meanwhile the design is progressing of the International Fusion Materials Irradiation Facility (IFMIF)[12], in which materials that will be developed for the ITER device will be tested, and fusion advocates are looking towards DEMO, which will be a prototype commercial fusion power plant.

We are, therefore, at a critical point in the development of fusion systems for electricity generation. Unless Australians take roles in these developments, the nation will become a backwater of research and engineering in this area.

However, just when other major economically developed countries are expanding their investment in this field as part of their participation in the ITER project, Australia's skills base, already in decline, is facing a generational cliff. At the heart of the crisis facing fusion research in Australia is a decline over decades in the number of people with expertise in this area, and now many research leaders are retiring.[13]

This skills decline will accelerate if Australians move to take up opportunities overseas and do not have an outlet for their research here to attract them back. It is time to form new generations of researchers with expertise in this area, looking towards the future when commercially viable fusion power plants are being built.

The Switkowski Report highlighted that skills shortages are a major constraint on the expansion of the uranium mining, processing and nuclear sector in Australia.[14] The situation in fusion-related science and engineering is more extreme. This especially in plasma physics, where much the base of Australian experts are within 15 years of retirement and there is little inducement for graduate students who wish to work in Australia to enter the field or for expatriate researchers to return to Australia. The capacity to teach basic plasma physics has become sub-critical. Today, only two universities – Sydney and the ANU – teach the subject at undergraduate level. The Prosser Report recommended that Australia seek to better coordinate its research for fusion energy across the various fields and disciplines in Australia.[15]

In addition, the period leading up to the start of experiments on ITER presents an opportunity for Australia to upgrade its expertise in areas related to fusion energy, so that when the massive volume of research data starts to become available, Australians have the capacity to analyse and utilise it.

The construction timetable for ITER is also an imperative for action. The ITER parties have already established their own responsibilities in the construction of ITER but some elements have not yet been allocated to any party. These offer the best avenues for a non-party, such as Australia, to be involved in the construction of ITER through contributing a specific component or components (a "machine contribution" is the term used in this strategy), as is further discussed in Section 2.2. The opportunity to propose, design and implement any machine contribution is limited by the ITER construction schedule. Therefore, in a few years Australia will be less able to play a significant role in this exciting development.

1.8 Risks of inaction

When considering investments on the scale – in quantum and timeframe – that is required for Australian engagement in the ITER project, it is essential to consider the consequences if no such investment is made. What would be the implications for Australia if the researcher effort in fusion-related science and engineering were to end and the researchers who specialise in this area were to leave the country?

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[12] IFMIF has been pursued under an IEA Implementing Agreement since 1995 by the EU, Japan, the USA and Russia.

[13] It was notable that a significant number of responses to the Issues Paper released in December 2006 were from researchers who are recently retired or who will retire in the next few years.

[14] Op cit, p2

[15] Op cit, Recommendation 14

It can be envisaged that when fusion energy reaches a commercial stage, there will be businesses seeking to sell generation systems around the world, including in Australia. Without a significant domestic base of know-how, the Australian government and Australian electricity generators would be poorly positioned to make good purchasing decisions.[16]

Australia will also face challenges in obtaining the skills needed for implementation and operation, as that there will be great demand for such skills around the world, due to the attractiveness of this energy form. With the ITER parties representing approximately 55% of the world's population, and the parties having an advantage in their skills base, Australia would suffer a delay or substantially higher costs before attracting sufficient expertise to implement its own fusion energy program, should it so choose.

In this regard it must be recognised that it is hard to rapidly ramp up research areas, especially given the recent and impending retirements of many of the nation's academics working in this area.

Industrial and spillover benefits of investment in fusion RD&E have been discussed above. Although investment in RD&E in many other fields could also yield industrial benefits and research spillovers, fusion science and engineering offers great *breadth* in spinoffs and spillovers into other fields. When it comes to marketing Australian innovations into global fusion energy markets, without a committed role in the international organisations working on fusion energy, Australians would face a tougher route to market. *With* a committed role, Australian IP would be better leveraged internationally.

More generally, Australia would lose the opportunity to promote its contribution to a major long-term solution to greenhouse gas emission, and the reputation that will be associated with what will be, no doubt, one of the largest international research programs of the first half of this century.

Australia does not face the loss of *all* fusion-related RD&E capacity. There are a number of other drivers for research that indirectly contributes to our nation's capabilities in fusion-related science and engineering. Materials and space plasma research are two strong examples. However, plasma physics is strongly driven by research that will lead to the development of fusion-related energy, and is the area under greatest threat of withering in Australia without new efforts being made.

The Switkowski Report provided many examples of the ways in which Australia has lost its capabilities in fission energy, and how this would present problems for introduction of nuclear power. Australia is facing the same prospect in fusion-related science and engineering unless action is taken, with potentially far greater ramifications due to the latter's anticipated advantages as an energy source.

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[16] ANSTO's contract of OPAL is recognised as an example of what can be achieved by a 'smart purchaser'.

2. "The Australian Fusion Initiative"

The establishment of a national initiative would provide the umbrella for the development of expertise and industry capabilities in line with the nation's long-term needs. It is proposed that this be called the "Australian Fusion Initiative". The Initiative would comprise:

- A fellowships program
- The development of an ITER machine technology contribution that could be used in other fusion-related systems as well
- Support for research infrastructure
- Support for travel and exchanges.

The Initiative would also coordinate international linkages and support commercial and public outreach.

There is no existing funding mechanism in Australia for such a mission-oriented program, which means that the Initiative would depend on new funding being established (see Section 6 for budget details). The Initiative would need to be sustainable over time, to give certainty and continuity to Australia's international engagement in this area and to meet the nation's long-term needs.

The Initiative would cover the broad range of Australian fusion-related research and education, including:

- Burning plasma physics
- Power plant modeling (including design, environmental impact, recycling and waste, and safety assessment)
- Nuclear, atomic and molecular physics
- Plasma diagnostic development
- First-wall and other relevant materials science (such as material development and synthesis, welding and joining, radiation and creep effects, and surface science and engineering)
- Control and data acquisition and analysis, and other information technology to meet the needs of fusion research.

"What should Australia do to build its capabilities in fusion-related research in the near term, and in the longer term?"

The development of commercially viable fusion energy will unfold over the next three to four decades. The strategy for fusion-related science and engineering in Australia should, therefore, focus primarily on development of expertise over a long timeframe.

An Australian role in the ITER project, as recommended in the Prosser Report, in particular supports the nation's long-term interests:

1. ITER is a key to the development of commercially viable fusion energy
2. It will be the hub of interest in fusion energy in the next decade, and will attract the interest of potential science and engineering students
3. An Australian role will strengthen Australia's international networks
4. Australian involvement would maintain Australia's reputation in this field, especially by applying existing Australian know-how.

In short, for Australia – as much as for the wider international community – ITER is a 'path' or 'means', as in the Latin meaning of '*iter*'. An Australian engagement in the project would be the central path towards the development of the capabilities that will be needed for the introduction of commercial fusion energy.

The Initiative would span basic theory, experimentation and applications.

Currently, the relevant Australian research effort is dispersed among at least nine universities and ANSTO, through a range of programs. Only the ANU has a significant effort, particularly through the H-1 National Facility (H-1NF), which has a key role as a platform for experimental magnetic confinement physics and which was substantially funded through the Major National Research Facilities (MNRF) program. Details of current research and education programs can be found in Appendix 3.

Given the distribution of activities and the long-term need, Australia will benefit most if any institution can participate in the Initiative, based on its ability to attract potential fellows and present a competitive case for funding. Excellence will be the driver. Individual institutions will be expected to provide support, however, as part of their participation. Moreover, although engagement in ITER is vital to Australians continuing to play a significant role in the field internationally, a diverse range of science and engineering should be supported, so as to meet the nation's long-term needs. For example, the highest impact contribution to the programmatic development of fusion energy may well come from theory or materials science.

Importantly, the Initiative would embed Australian efforts in international programs, including ITER and IFMIF, power plant conceptual studies, and the stellarator physics program. The 2006 PMSEIC working group report highlighted the importance of promoting Australian science to the world, identifying international opportunities for Australian scientists and providing timely access to knowledge and scientific and technical data. The Initiative would meet this need. One result would be that Australia would be in a much stronger negotiating position on a whole rage of fusion-related issues in the longer term and key individuals would have the contacts needed to support Australian decision-making regarding fusion energy as an option for this country. Being integrated with international programs would also ensure that skills and research training are at an international standard.

A description of each element of the proposed Initiative follows. Governance and management are discussed subsequently.

2.1 Fellowships

A fellowship program would enable Australia to build up its base of researchers with expertise in fusion-related research and engineering. Because we will need to develop fusion-related expertise over decades but need to start now, the focus of a fellowships program should be on early- and mid-career researchers. This is also consistent with wider themes in government policy, as seen, for example, in the Switkowski Report and the Hon. Julie Bishop's focus on early career researchers in her capacity as Minister for Education, Science and Training.

It is proposed that fellowships be established comparable to Australian Research Council (ARC) Queen Elizabeth II Fellowships. They would resemble the tenure-track fellowships offered by the Australian Institute of Nuclear Science and Engineering (AINSE), which are offered to scientists with three–eight years' postdoctoral experience. These would not be renewable.

By gradually increasing the number of fellows over several years and encouraging fellows to seek other funding sources, by the time DEMO is in preparation Australia would have a base of people with relevant international experience and networks. DEMO will be designed even before ITER is completed.

It is proposed that four fellowships be offered in the first year, and then four additional fellowships each year to follow. The terms would be for five years, meaning that the number of participants would plateau from the fifth year onwards.

The fellowships would particularly be used to attract back to Australia some of the early- and mid-career members of the international network of Australians undertaking fusion-related research. Many are keen to return.

Fellows would not be expected to spend all their working life in Australia, and overseas experience would, in fact, continue to be very important. Some would seek work on the ITER project and other fusion-related facilities, following in the footsteps of the many Australians who can be found in such facilities overseas today. Their ongoing relationships with Australia would support collaborations and Australian engagement, as has been seen in the process of shaping Australia's potential engagement in ITER. In addition, some would want to return at a later stage in their careers. However, such 'brain circulation' – as distinct from 'brain drain' – will require opportunities here in Australia, in research, government or business.

Eligibility

These opportunities would be open to individuals across Australia (or coming to Australia) as the need is to develop an overall national base of expertise. The fellowships would be able to be taken up at any relevant institution in Australia, on the principle discussed above. They should be competitive to ensure they deliver excellence and acknowledge potential. This approach would also enable all aspects of fusion-related research in Australia to be supported, regardless of the ITER machine contribution (discussed below) and later technologies. The fellowships would enable Australians to be involved in a range of international fusion-related developments.

The fellows would be primarily researchers: undertaking research and disseminating their findings through the most appropriate public and commercial mechanisms. Fellows would be expected to maximise Australian involvement in international fusion power developments. However, holders of the fellowships would be expected to undertake teaching and supervision as well as research, in addition to being involved in school, undergraduate and community awareness-raising activities, to encourage students to study fusion-related science and technology and to build understanding across the wider community. In some areas, such as materials science, fellows could also be extensively engaged in industry linkages.

Fellows would be selected on their quality, in line with the Initiative's overall focus on excellence, and the relevance of the proposed fellowship to the development of fusion capabilities in Australia over the longer term. The latter would cover such factors as candidates' career plans, proposed research activity and the institutional context for the proposed research. The intention would be to ensure that the fellowships address the overall goals of the Initiative and are directed to research that is genuinely relevant to fusion-related science and engineering. Nonetheless, a significant amount of the research effort would probably be applicable to other fields as well as fusion energy. New materials is one example of such multiple applications.

Leveraging

The fellowships would be intended to seed activity. Applicants would be expected to apply for other funding, for example from the ARC. This would foster longer-term sustainability of the Initiative.

It is proposed that fellowship funding includes a component for materials and minor infrastructure. The way in which this would be spent would be determined by the host institution but it would be expected to demonstrably support the fellows' research plans.

2.2 ITER machine contribution

Providing Australian technology for use in ITER ("the machine contribution") would represent a flagship for Australia's national effort in this area. It would draw on researcher, industry, and wider community interest and support.

Criteria

The machine contribution should satisfy several criteria, as follows:

1. Australia must receive clear, valuable benefits from making such a contribution, as discussed in Section 5, and be recognised as a supporting participant.

2. It is important that the machine contribution be a tangible item or items that can be described as “Australian”, and promoted as such by Government, researchers and industry. Other potential Australian contributions to the development of ITER can be made by researchers through collaborations and dissemination of their research findings.
3. For successful engagement with the ITER Organisation and/or parties, it is necessary that Australia only consider items that are unassigned, that is, that are thought to be needed or beneficial for ITER but do not currently have funding in parties’ plans.
4. There must be a strong ‘pull’ for the item being proposed, to ensure the contribution would be applied and valued, and have impact. Australia must be able to see how the contribution would fit into longer-term plans and influence international trends in science and technology. The item must either accelerate or enhance ITER’s capability and be consistent with project success criteria and the full-partners’ rights and roles. Unless the item is highly valued, Australia would not be able to use it to obtain benefits from its involvement (as per point 1 above).
5. For Australia’s benefit it is necessary that the item be recognised for its excellence on a global scale, so it can enhance Australia’s international standing in fusion-related science and engineering.
6. It should incorporate protected intellectual property, to help Australia capture the benefits of its work.
7. It should be based on existing know-how and/or technologies that can be efficiently and cost-effectively taken to the next level of meeting ITER’s needs.
8. Development and construction of the items must be able to be achieved within the Initiative budget.
9. The contribution should represent good value for money for Australian taxpayers.
10. The item must be backed by a team with a solid track record in delivering to deadlines, to ensure ITER timescales are met, and to budget.
11. There must be incentives for the institutions(s) hosting the research to be committed to the activity. This would include ensuring that the development program would satisfy wider university performance measurements, such as student supervision, publications and quality.

Preferred contribution

The contribution would be, by definition, a subsystem in a niche area. The workshop held in October 2006, responses to the December 2006 issues paper and discussions with international researchers involved in the ITER project indicate solid support for a plasma or control diagnostic in that regard.

- The ITER Organisation recognises the benefits, and even needs, for additional measurements being made and the need for additional diagnostic systems. About 40 large-scale diagnostic systems are foreseen.
- Because taking measurements through diagnostics is a developing area, and some aspects have taken shape since the ITER device’s design was established in 2001, there are uncredited systems in this area.
- The addition of these systems would allow the ITER device to operate at the highest possible level of performance and provide knowledge for possible use on the fusion reactors that will follow ITER. The ITER Organisation is undertaking a major review, including an assessment of the integrated measurement capability against requirements, which will highlight needs that have not yet been met.

- The detailed measurement of plasma conditions in the extremely hostile environment existing inside a fusion reactor represents one of the most difficult challenges faced by ITER, so related work will have a high priority and visibility.
- The required progress in key areas of the science underpinning fusion energy will not be possible without a significant expansion of plasma diagnostic capabilities, meaning diagnostics are of vital importance to the field around the world.[17]
- There has been a long tradition in Australian universities, particularly at Sydney and the ANU, of developing novel plasma diagnostic techniques that are highly regarded internationally and have been adopted by overseas groups. For example, in recent years several of the highly innovative spectroscopic diagnostic techniques and devices invented by Professor John Howard of the ANU have been and are being acquired for use on major overseas facilities. (See Appendix 4.)
- Many of the students who have worked on these are now working in fusion research institutions overseas, providing a broader network for Australia in this area.
- There has been strong informal interest and encouragement by leaders of the ITER diagnostics team in Australian expertise in this area.

A tile erosion monitor is a strong candidate as a potential diagnostic. Excessive erosion is one of the challenges faced in a fusion reactor and this technology brings together Australian strengths in diagnostics, surface science and materials, and involves a number of institutions. Another candidate is optical imaging systems for the plasma divertor region. The H-1NF heliac at the ANU could be enhanced to provide a toroidal plasma confinement environment optimised for developing ITER diagnostic systems, given some infrastructure replacement discussed below. The ANU also has optical expertise. Materials expertise at the Universities of Newcastle and Sydney could be integrated with the ANU's expertise in such a development effort. In time such activity would benefit Australia's physics program.

Given there is general consensus about a diagnostic, the process of engagement could start with scoping needs, ascertaining costs, determining responsibilities and establishing the mechanisms for engagement (see below). The details would need to be prepared in close consultation with the ITER Organisation and probably some specific partners. This would be undertaken by way of a working group focused on this subject.

Development of a diagnostic might encompass the initial research towards ITER needs and building a full-scale mock-up before commissioning the final construction of a properly "hardened" instrument suitable for the ITER environment. Australia has businesses that are able to undertake the necessary construction, assembly, testing and calibration work. Industry awareness of the opportunities in fusion-related science and engineering would begin with the process of costing the contribution.

Alternatively, it might be proposed that Australia undertakes the work up to the mock-up stage with the final system built elsewhere. However, this would require some funding for this subsystem to come from other sources, and such subsystems are currently uncredited (that is, there is no defined other source).

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[17] *Plasma Science, Advancing Knowledge, in the National Interest, National Research Council of the National Academies*, Prepublication report, May 2007, pp116-117. The report notes that "National initiatives focused on enhancing analytic theory, improving computational algorithms, and making dramatic improvements in the diagnostics deployed at existing facilities would make breakthroughs in our understanding of the key burning plasma physics issues…. ITER needs a deeper understanding of these key plasma physics issues; the party that comes to the ITER table with this expertise will have a strong position in the international magnetic fusion program for at least fifteen years." The report recommends that the US undertake a diagnostic initiative (p138, prepublication version).

ITER's design incorporates a modular approach and the design and construction process will be long-term. It is not anticipated that the diagnostic would be installed before about 2016, which is the year in which the assembly of the tokomak is due to be completed.

There is a good case for starting with a single item, to demonstrate to Government and international individuals and organisations that Australia is committed to and capable of seeing this through, and to establish the model for engagement.

Subject to budget, subsequent ITER machine specific contributions could be assessed in later years, or items for IFMIF and DEMO, which might start earlier than has been anticipated and could be an outlet for Australia's research in this area.

Other candidates for contributions include a divertor wall erosion monitor or a dust monitor, diagnostics of fluxes and other conditions, or first wall materials for later ITER testing, and DEMO.

2.3 Australian key infrastructure enhancement

To ensure rapid development of a diagnostic instrument, it will be essential that current facilities are upgraded to international standard relevant to the execution of this task. A fund to support essential infrastructure enhancement is proposed in the first three years. The need for such funding can be argued for a number of systems, such as Australia's toroidal magnetic confinement plasma facility, the H-1 heliac, which would require some upgrades in order to be used as a test bed for ITER diagnostic development. International experts, including ITER representatives, would be engaged in evaluating and prioritising the allocation of this funding.

The Australian ITER contribution will most likely be an optical diagnostic utilising possibly laser and/or spectroscopic systems, and likely focussing on the important plasma divertor region. An Australian high-temperature plasma facility is critical in mounting a successful ITER diagnostic.

1. To interpret sightline-averaged optical measurements, it is extremely important to take account of spatial variations in plasma properties such as brightness, temperature, magnetic field strength etc. H-1 is able to address this problem – it is an extended, inhomogeneous, magnetised radiating source.
2. It will eventually be essential to tackle issues such as vacuum compatibility, susceptibility to electromagnetic interference, magnetic fields and plasma background radiation (x-rays through to optical). H-1 is a natural radiation source for this purpose.

Access to a fusion-relevant national plasma facility would also be regarded by much of the international community as necessary for Australia to provide a fully-qualified machine diagnostic.

To prepare H-1 for such a development, the machine will need to access plasma regimes relevant to ITER divertor conditions. This will require various heating and vacuum system upgrades to achieve higher plasma parameters and to manage impurities.

2.4 Infrastructure and equipment investment fund

In some fusion-relevant areas – for example, numerical modelling of plasma phenomena – Australia is well endowed with infrastructure, such as super-computers and fast data networks. In other areas, infrastructure is ageing or insufficient for a larger scale effort or new fields. Without world-class facilities, Australian researchers will be hampered in achieving world-class results, in attracting top students and in equipping students with skills applicable on leading international fusion energy systems.

A larger fusion-related RD&E effort would require appropriate facilities. The Initiative could be a source of funding for co-investment in new and enhanced infrastructure. It would be leveraged against sources such as ARC Linkage Infrastructure, Equipment and Facilities

(LIEF) grants and institutional funds, with the Initiative providing up to 50 per cent of the necessary expenditure. The infrastructure leveraging fund would be operated as a contestable scheme, enabling funding to be directed to the highest priority needs, areas of most significant demand and the best use of the funds.

Both senior researchers and Australian Fusion Initiative Fellows are likely to be sources of proposals. This funding would be in addition to the funding of the fellows and not dependent on the allocation of fellowship funding, although trends and plans in that regard would be influential factors.

2.5 Key infrastructure operation leveraging fund

The Initiative would also support co-investment in personnel costs associated with operating infrastructure that furthers the national fusion-related science and engineering effort. This would ensure that the facilities are available for use by researchers and industry, and provide technical competence that Australia will need in the longer term in addition to scientific capabilities. It would be leveraged on the basis of up to two-thirds of funding coming from the Initiative and one-third from other sources. (At present, Australian research facilities have limited options in seeking funding for operations.)

The minimum duration of these commitments would be determined by the particular infrastructure, but it would not be expected to be less than three years and is more likely to be five years. These commitments would be subject to satisfactory performance and adjustment in later years if more pressing priorities emerge that support the Initiative's overall objectives.

2.6 Travel and exchanges

The Initiative would also support international engagement via:

- Grants for researchers to travel to conduct research at overseas facilities and participate in meetings and conferences that relate to major international fusion-related developments, notably ITER
- Student exchange, enabling Australians to work at overseas facilities, with preference given to facilities involved in the ITER project
- Enabling visiting scientists to come from overseas facilities for some months at a time, primarily to contribute to teaching programs in Australia
- Supporting attendance by early- and mid-career researchers and invited international speakers at an annual Australian workshop on fusion related research.

This element of the Initiative would be in line with the need recognised by the PMSEIC working group on global science engagement for a strategic way to facilitate skilled and creative people moving to and from Australia. It would encourage greater Australian participation in various international programs in fusion-related science and engineering.[18]

[18] For example, Dr Didier Gambier, the EU delegation speaker at the 2006 workshop on Australian engagement with ITER, and now Director-General of the European Domestic Agency ("Fusion for Energy"), recommended that Australia take a more active role in the International Tokamak Physics Agreement (ITPA), which is the research framework that underpins ITER and burning plasma science. However, Australian researchers face significant financial hurdles in participating in such activities.

3. Managing the Initiative

Management of the Initiative would require proper, effective governance arrangements and administrative support.

Who will be responsible?

An expert committee would provide oversight and strategic leadership, while management would be by a small team.

3.1 Oversight

A committee should be formed to select fellows, infrastructure funding proposals and travel and exchange proposals. Given the size of the Australian fusion-related science and engineering community, it is essential that funding decision-making and consequent performance oversight be demonstrably objective. The committee membership should, therefore, be drawn from:

- Both Australian and international organisations, the latter especially as independent voices and for their global perspective and relationships
- Across the spectrum of Australian fusion-related science and engineering
- Researchers who are currently active in fusion-related areas as well as those who are not, such as former researchers who have moved into other roles or retired, and individuals from industry or other parts of the Australian science and engineering communities
- Individuals who are committed to a high standard of objective decision-making.

3.2 Management

A director and support staffing would be required to oversee the various aspects of the Initiative (such as disbursement of funds, fellowship promotion, the contract with the team developing the ITER machine contribution, performance monitoring and reporting on all aspects of the Initiative). The position of director would be advertised internationally. Some administrative support could be provided, on a charged basis, by the organisation that hosts the Initiative office (discussed below). It is important that the management of the Initiative does not absorb funds that would otherwise be spent on RD&E.

The office supporting the Initiative would pursue the profile necessary to foster significant collaborations overseas: at various levels and between different organisations (bearing in mind that certain aspects of the international fusion-related research effort are based on government-to-government agreements and, therefore, would be outside the mandate of the Initiative office). It would act as the Australian intermediary with international fusion energy bodies. It would also work with the bodies that are the primary contact points in related areas, such as ANSTO regarding the IAEA, the Department of Industry, Tourism and Resources (DITR) regarding the NEA and IEA, and the Department of Education, Science and Training (DEST) regarding the OECD Global Science Forum. It would also interact closely with science attachés of ITER partner missions in Australia. It would have a program to benchmark Australian research efforts through partnerships with leading centres overseas, to provide input to decision-making. This would be over and above networking of individual researchers and organisations.

3.3 Hosting the Initiative

The Initiative might be located at AINSE or a university. The location should be strategic and acceptable across the community.

- AINSE's remit is to advance the cause of education and training in nuclear science and engineering. It is focused on building national capabilities and has a recognised model, acknowledged success and long experience in bringing together multiple institutions, fostering early career researchers and managing research programs. All universities engaged in fusion-related research and education are AINSE members, as is ANSTO. AINSE's committee system could provide a model for funding decision-making.

- There are a number of other models for hosting the Initiative, including the Australian Synchrotron Research Program, which is managed by ANSTO, and the Forum for European-Australian Science and Technology Cooperation (FEAST), which is hosted by the ANU.

Regardless of where the Initiative is based, it is vital that it has its own distinct identity: that it is seen as being "at" that location, not part of the host organisation, and being driven by the Initiative's objectives, not those of the host.

3.4 Performance measurement

A system of performance measurement is required to ensure that the Initiative delivers value for Australia. Recurrent funding assessment would be based on performance measures collated in annual reports. The following performance measures relate to activities that would be funded under the Initiative.

Fellowships

- Ratio of fellowship applications to appointments (level of demand)
- Fellowships filled each year (level of quality)
- Level of funding attracted by fellows from other sources (leveraging)
- Number of fellows moving from Initiative funding to other sources of funding (sustainability)
- Fellows' research productivity
- Evidence of effective management of fellows' research programs
- Retention of fellows in Australia (contribution to national capability following completion of fellowship)
- Fellows' participation in outreach activities
- Involvement in student research training (where applicable)
- Fellows' leadership

ITER machine contribution

- Adherence to agreed schedule
- Adherence to budget
- Satisfaction of Australian research leaders with access arrangements that are enabled by ITER machine technology contribution (see Section 5)
- Commercial opportunities attributable to ITER machine contribution
- New Australian IP arising from development of the ITER machine contribution

Infrastructure components

- External user satisfaction with facilities that are financially supported by the Initiative
- Level of usage of facilities that are financially supported by the Initiative, by:
    - Users overall
    - Users external to the host facility
- Proportion of leveraging from other funding sources, from:
    - Contestable sources
    - Institutional funds (not directly contestable)

Travel and exchanges

- Participation by Australia-based researchers in ITER-focused forums (and other international programs in the longer term)

- Number of exchanges supported
- Scale of the annual conference
    - Number of attendees
    - Number of attendees from other countries
    - Number of early career researchers supported
    - Number of students involved

Management and outreach

- Industry involvement in activities funded under the Initiative
- Number of members of the Forum (see below)
- Awareness in Government (survey about every three years)
- Media references arranged by the Initiative and by the Forum
- Number of visits, or number of students presented to

Performance measurement of related activities

Members of the wider fusion-related science and engineering community should be encouraged to set rigorous measures for performance and be accountable for those. The wider community should be particularly mindful of the implications for funding in the operation of the Research Quality Framework, which aims to financially reward excellence in research and reduce funding of research that cannot demonstrate excellence.

In addition, research institutions within this community are encouraged to factor national research leadership into their staff assessment procedures.

4. Essential strategy components

4.1 Pivotal role of the Australian National University

Australia's largest centre of capability in fusion-related science and engineering is located at the ANU. In particular, there has been considerable investment in magnetic plasma confinement research related to fusion by the ANU and the Australian Government through the MNRF program. As noted in Appendix 3, the ANU has a number of groups involved in fusion-related science and engineering, and the ITER machine contribution proposed above would be based on know-how developed at the ANU. The University will, therefore, play a pivotal role in the success of this strategy.

What else is needed to implement this strategy?

As well as the Australian Fusion Initiative, this strategy's success depends on the further development of all the key existing aspects of the Australian fusion-related science and engineering community, most notably the capabilities of the ANU, the international network of Australian researchers and the forum of researchers and research organisations that has driven the development of this strategy.

The ANU's capability could become much more the nucleus of a national effort by increasing the formal linkages between the ANU in this area and other institutions, attracting more students and improving its experimental facilities.

1. Co-investment from other institutions in infrastructure at the ANU would enable new infrastructure to be purchased and existing infrastructure to be upgraded. The ARC's LIEF scheme could be one trigger in such an arrangement. (See Section 6.) Infrastructure developed with co-investment would require new collaborative governance arrangements involving participants (perhaps similar to the governance of a Cooperative Research Centre).
2. The limited external use of the plasma research facilities at the ANU by the wider Australian research community both reflects the diminishing user base and indicates that the existing access arrangements via AINSE are not sufficient to encourage usage. While growth in the size of the overall Australian research community will see growth in usage, research outreach activities should nevertheless be expanded. One mechanism could be the establishment of a user group, with representation from the Initiative, and including Australian and international users and international experts, with an external Australian Chair. This group would be primarily focused on promoting and increasing usage of this facility and others at the ANU supported by the Initiative.

4.2 Enhancing the Forum

The "Australian ITER Forum" is changing its name to reflect its broader interest in fusion energy.

The Forum is distinct from the Initiative. The Forum is an umbrella for all researchers involved in fusion related science and engineering in Australia. It will continue to be a communication vehicle within that community, especially organising the proposed national conference (see "Travel and exchanges", above). It will also continue to seek to contribute to the development of Government policies relevant to fusion-related science and engineering, such as climate change, energy and research policies.

The Initiative host would become responsible for the Forum's online presence, which is currently provided by AINSE.

The Forum should become a formally defined organisation with a constitution, enabling clearer lines of membership, annual elections and a more structured decision-making process. This might be the body that becomes responsible for ongoing review of this strategy.

4.3 Australian overseas fusion network

A network of Australians overseas and alumni of the Australian Fusion Fellowships could be brought together to advise Australian students, researchers and businesses about opportunities in other countries, and to advise students and researchers about opportunities in Australia. There are models in the alumni network of EU Marie Curie Action fellowships[19], FEAST[20] and the networks in Australia that aim to support research collaborations with France, Germany and Italy.

See Appendix 5 for more information on the current international network.

4.4 Evolution and growth

The fellowship program would focus on development the next generation of fusion researchers. However, the overall research community needs to be strengthened, especially at higher levels where many retirements have recently taken place or are impending. Existing Government programs, such as those funded by the ARC and institutions such as ANSTO, can play important roles in this (also see Section 6.)

It is expected that collaborations may well grow over time towards establishing a formal centre or centres which would be better positioned to attract funding through competitive programs. Australia should be starting to rebuild its base of expertise now, and this does not depend on a centre being established in the near future. Moreover, it is essential that we build a consolidated effort without casting in stone those who would be participants in a formal structure and those who would not be.

Meanwhile, and even for those who do not participate in any later formal centre, the Initiative would provide many of the same high-level benefits, namely a focus for international engagement; support for staff development and retention; a cohesive, ongoing source of funding; and an umbrella for the Australian research effort.

In terms of international programs, the medium-term emphasis should be on providing the basis for Australian organisations to play a role in DEMO.

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19 cordis.europa.eu/mariecurie-actions/home.html
20 www.feast.org

5. International engagement

> **"How should we manage engagement?"**
>
> There are advantages for Australia in engaging directly with the ITER Organisation.

The Australian Fusion Initiative would be deeply integrated with international programs at a number of levels. Many interactions – including those of Australian Fusion Fellows – would be primarily managed by individual institutions and researchers, as they are today, although the Initiative office would have a mandate to foster interactions.

The most pressing question for the Australian fusion-related science and engineering community is to how best to manage international engagement towards the Australian ITER machine contribution. This was especially emphasised in the Prosser Report.[21]

The ITER Organisation is responsible for ITER planning, design, integration, quality assurance, safety, licensing, schedule installation, testing, commissioning and operation. The ITER Joint Implementing Agreement provides for cooperation with institutions from countries that are not ITER parties.[22]

Direct engagement with the ITER Organisation would provide the most direct linkages with the ITER project. It would have a high level of impact, and having direct involvement in the ITER project would be important to capturing spillover benefits, such as other research collaborations, student exchanges or commercial opportunities. In addition, a formal association with the ITER Organisation would enable greater involvement in post-ITER developments, which are already being planned. Australian association with the ITER Organisation, and through this all the ITER partners, would position Australia well to access post ITER developments, by when Australian capabilities would have further developed.

5.1 Ensuring benefits to Australia

The arrangement for Australia to contribute to the ITER machine must provide some defined benefits for the nation. Through an engagement with the ITER Organisation, the nation should be seeking, for example:

- To be able to place Australian Fusion Fellows within the ITER Organisation on an exchange basis
- To be able to have Australian representatives as observers at major meetings, especially those involving longer term directions
- To retain full IP rights over the item it contributes (since it does not have the opportunity to share in IP generated by the ITER parties)
- To host scientific visits to Australia by individuals from the ITER Organisation who are involved in the integration of the item into the ITER machine
- To have open access to data generated in ITER experiments (see Section 1.7)
- To participate in the Broader Approach, which includes the International Fusion Materials Irradiation Facility, the International Fusion Energy Research Centre and the Satellite Tokamak JT60-SU. Currently Broader Approach activities will be open to other ITER parties for their participation in research activities on the condition that Japan and the EU approve, which excludes Australian involvement.

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21 Chapter 12

22 See Article 19 International Cooperation, www.iter.org/JIA_text.htm

5.2 Establishing engagement

Australia would be ploughing new ground in seeking to establish direct engagement with the ITER Organisation and there are a number of people who do not believe Australia, or indeed any other country, could succeed in such an approach. The formal basis for third-party agreements has not yet been established. The first country to approach the Organisation is likely to be a test case in this respect – and that could be Australia. Australia would be able to draw on the credibility that comes from its long involvement in the field, the international network of Australian fusion scientists and the goodwill of the scientific and technical teams that attended the international workshop in Sydney in October 2006.

While it is proposed above that the ANU's diagnostics technology form the basis of an Australian machine contribution, and this has been central to discussions to date, negotiations with the ITER Organisation would be substantially government-to-government. The fusion-related science and engineering community's role – and especially institutions that would be involved in the machine contribution – would offer and provide briefings, contacts and other forms of input as necessary. The community should nominate individuals to provide expert advice to Government at short notice. The Australian Government also has counsellors overseas – including those of DITR, DEST and ANSTO – who can assist.

5.3 Relationships with ITER parties

If a direct relationship with the ITER Organisation does not come to fruition, Australia should seek a collaborative relationship with domestic agencies of the ITER parties for the development and implementation of the ITER machine contribution.[23] These agencies are responsible for detailing design, procurement, delivering and supporting installation.

However, this is not a viable option for a diagnostic, as such a contribution depends on Australia having some form of formal status as a supporting participant, as discussed above.

In addition, the relative disadvantages of engagement via an ITER party are that Australia would have more limited benefits – as the relationship would be with a single agency – and effort would be needed to ensure recognition internationally of Australia's contribution, as it would be subsumed in a party's contribution. The contribution might also be less valued as it might not yield an *additional* system for ITER but might rather be a substitution for a system that a partner already intended to provide.

However, a number of ITER parties have been receptive to the idea of Australia engaging with them, as part of their contribution to ITER. This has been explicitly discussed with the EU and Japan, and China and Korea have expressed interest in collaborations in the Asia-Pacific area forming part of their contributions to ITER. Australia has strong collaborative links with the EU, the US and Japan in fusion-related research in particular, and S&T more generally. In addition, the basic framework already exists for international collaborations of this type, i.e. Australian research teams and companies becoming involved with international research and projects.

The EU and Japanese agencies are especially attractive as potential partners. They are leading the Broader Approach and Australians have extensive collaborations with both these countries, which would provide the personal relationships and trust necessary for successful collaboration.

- The European Joint Undertaking under the Euratom Treaty for ITER and the Development of Fusion Energy, is 'Fusion for Energy'. Euratom has overall program management responsibility (including funding) and represents the program externally, while the Euratom Fusion Associations link EU member states (and countries

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23 Brazil is pursuing involvement via EURATOM. Canadian scientists have been involved in the ITER project until now mainly through the EU, although this was under arrangements prior to the present ITER Organisation.

associated to the Euratom Framework Program [FP]) and Euratom. This organisation will also provide Europe's contribution to Broader Approach projects.

- The Japanese Domestic Agency, JA-DA, procures and delivers ITER facilities and equipment allocated to the Japanese in-kind contribution. Australia’s material research strengths give it strong potential for engagement in IFMIF, which will be located in Japan. Japan also has a ‘Fusion Forum’, which contributes to the ITPA and ITER and which might assist in Australia taking a greater role in the ITPA (as discussed in Section 5.5).

5.4 Forum for non-parties

Australia might also propose the formation of a forum with entities from other countries that are not parties to ITER but which are active in the field, such as Brazil and Canada. The intention would be to foster effective frameworks for interaction with the ITER Organisation and non-parties.

5.5 Other mechanisms for international linkages

Strategic partnerships are a promising avenue for leveraging our contribution to fusion science in selected research areas. Research collaboration could be undertaken at a greater level in such contexts as the EU Framework Program and the Stellarator Agreement. Engagement by Australian Fusion Fellows and others could be the basis of new research linkages with China, India and Korea, with which national research collaborations in fusion-relates areas are less developed. China is promoting involvement in its EAST tokamak experiment, as is Korea in its KSTAR tokamak. Overall, multi-party engagement would mean a larger and more diverse portion of the Australian community could be utilised.

Australian researchers should also increase their international engagement by participating in the International Tokamak Physics Agreement,[24] through joining ITPA workgroups. Participation in ITPA would substantially increase Australians’ involvement in ITER physics activities, although it would only marginally increase their involvement in the ITER project itself as only the ITER Organisation will be charged with the ITER program. Overall, the involvement of Australians in ITPA complements national engagement in ITER via a machine contribution. Unlike a machine contribution, Australian participation in ITPA would not need to be centrally managed, and is more a matter for individual researchers and research teams.

Another possibility is to become more involved in the International Fusion Research Council (IFRC), an advisory body to the IAEA that meets yearly to recommend and approve the plans of fusion technical meetings. The IFRC is important in the wider context of fusion power development. The IFRC will act as the fusion consultation body with the non-ITER community. It will also facilitate progress towards DEMO in parallel with the development of ITER, such as holding DEMO workshops. Engagement via the IFRC would be compatible with Australia’s strong standing in the IAEA. There appears to be the possibility of increased Australian involvement in the IFRC.[25]

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[24] ITPA members validate experimental data according to an agreed format; analyse results of experiments to advance understanding of fusion plasma physics; organise manage and update databases; develop theoretical models and simulation results to explain and reproduce experimental results; undertake studies of fusion plasma performance in burning plasma tokamak devices; and identify and resolve key physics diagnostics issues which might arise in plasma control and analysis of a burning plasma experiment. See itpa.ipp.mpg.de/.

[25] At present this committee has six representatives from Europe, four from Asia and one each from the Russian Federation, the USA and Brazil. The Brazilian member is the only one not from an ITER party (noting that EU member states, as well as the European Commission, have representatives on the Committee). See http://www-naweb.iaea.org/napc/physics/ACTIVITIES/IFRC.htm. It is notable that an

Involvement in IAEA Coordinated Research Projects on plasma physics and on materials and systems for fusion research could also increase Australian researchers' international linkages.

Research teams should be pursing opportunities to participate in the EU Seventh Framework Program, by, for example, registering capabilities and interests on the FP partners database[26] and asking EU colleagues about their plans, with a view to joining their proposals. As Australia is a 'third country' in FP proposals, any involvement will be by way of proposals originating in Europe, and potential collaborators should be identified and discussions held well before calls are issued.

In fusion plasma theory and modelling there are international collaborative forums such as the Transport Task Force meetings and working groups[27]. A larger theory and modelling community would enable greater and more regular participation, and thereby enhance access to cutting-edge research.

Increased involvement in bodies such as the above could be supported by the fellowships, and travel and exchange funding discussed above, as well as by other grant sources. While important to the overall national fusion capability, none of these additional forms of linkages is an alternative to direct engagement in the ITER project.

Australian, Max Brennan, is a former chair of this committee. Charles Watson-Munro, who was also prominent in Australian science, was a founding member of the IFRC.

26 cordis.europa.eu/partners-service/dc/index.cfm?fuseaction=connexion.dologin&location=update.listProfile&section=Partners

27 See http://fusion.gat.com/conferences/ttf/announcement.html

6. Costing and funding

The ITER project, IFMIF and DEMO are operating on timeframes that are much longer than Australian research grant cycles. While short-term grants can contribute to the fusion energy R&D effort, they are not sufficient to enable Australian researchers to make commitments on the scale that ITER parties would seek to match their own commitments. Confidence will be needed that research funding will continue on the same timeframe as required for ITER. Moreover, existing programs do not address the full scope of needs.

The Australian Fusion Initiative can therefore only be established with a new program for funding.

> **"How can this be funded?"**
>
> The Australian fusion-related science and engineering community is seeking funding from the Australian Government for the Australian Fusion Initiative, which would leverage other sources of funding as well.
>
> A number of other existing programs would also support the wider effort.

As noted in the 2006 PMSEIC report on global science engagement: "Organisations and individuals involved in the initiation, definition and execution of global science programs will need significant long term funding to follow a protracted process of international collaboration." The report also noted that existing linkage programs do not offer support of sufficient duration to realise the full potential of collaborative projects.

6.1 Australian Fusion Initiative components

The budget for the seven components of the Australian Fusion Initiative is $62,750,000 over 10 years. The budget has been set out over this length of time as it is the timeframe for the ITER machine contribution. The budget is detailed in Appendix 6.

A. ***Fellowships*** –A fellowship at a QEII level costs approximately $200,000 per year, being $130,000 for salary plus on-costs and the remainder for research costs, such as materials, minor infrastructure, consumables and travel associated with the fellow's research. Four fellowships therefore equates to $800,000 per year. Four fellowships would be added each year until the fifth year. The indicative budget is, therefore $32 million over 10 years.

B. ***ITER machine contribution*** –The indicative budget for the diagnostic itself is $9.25 million. The annual allocation for this element would ramp up and then decline in the later years.

C. ***Key infrastructure enhancement –*** Updates and enhancements required to bring essential infrastructure to a minimum standard for development of an ITER diagnostic contribution, for which the estimated budget is $1.8 million over three years.

D. ***Infrastructure and equipment investment fund*** for new and enhanced infrastructure – A competitive, leveraged fund estimated at $500,000 in the first year, rising to $1,000,000 per year. The total indicative budget is $9.5 million over 10 years.

E. ***Key infrastructure operation leveraging fund*** – A competitive fund set to start at a low level of $50,000, rising to $300,000 from the third year. The total indicative budget is $2.5 million over 10 years.

F. ***Travel and exchanges*** – For the competitive scheme for travel to facilities and meetings as well as an annual national conference, the estimate starts at $300,000 in the first year, rises to $400,000 the following year then to $500,000 per year thereafter. The total indicative budget is $4.7 million over 10 years.

G. ***Management*** – Estimated at $300,000 per year, giving a total indicative budget of $3 million over 10 years. This covers the director (about $170,000 including on-costs), support staff ($90,000 including on-costs) and such expenses as office operation and travel.

6.2 Leveraging other programs

A number of other programs offer great potential to support the fusion-related research effort, especially when used as part of a wider strategy. Contestable funding schemes could be used on their own or to leverage Initiative funding.

Senior researchers

- Forum members should identify Australians involved in fusion-relevant research overseas who are contenders to be Federation Fellows. Having additional Federation Fellows in this field in Australia would fill the need for top-level researchers. Federation Fellows are attractive to host organisations, despite the high organisational funding required, because they bring substantial additional funding (thereby leveraging the host's own funds) and enhance the reputation and programs of host institutions. Such researchers also become hubs of activity, seeking other funds for their teams. Already some names have been proposed for such high level fellowships. However, negotiating with potential candidates takes considerable time, and such discussions would be better undertaken once the foundations of the Initiative are in place.[28]
- Contenders for Federation Fellowships should also be considered as contenders for ANSTO Distinguished Researcher Fellowships, which offer similar salaries and benefits. These fellowships are located at ANSTO, and they are required to work within ANSTO-specific areas, such as materials.

Infrastructure

- As discussed in Section 2, ARC LIEF grants could be used in leveraging infrastructure investment.
- Institutional funds could be sought to leverage infrastructure.

ITER machine contribution

- ARC LIEF grants could be applicable to some aspects of the machine contribution. There are examples of LIEF funding offshore infrastructure, although not at this level.
- ARC Linkage Project grants could be considered to support the ITER machine contribution if it is undertaken with strong industry involvement.

Collaborations with various countries

- ARC Linkage International Awards funds Australia-based researchers to participate in joint research projects with overseas researchers, establishing new collaborations and strengthening ongoing collaborations.[29]
- ARC International Fellowships provide salary and associated funding to outstanding research fellows to work in eligible Australian or overseas organisations.[30]
- ARC Linkage International Internationally Coordinated Initiatives fund collaborative research proposals in targeted areas. They are funded occasionally from the ARC in

[28] www.arc.gov.au/ncgp/fedfellows/ff_default.htm
[29] www.arc.gov.au/ncgp/lx/lx_default.htm
[30] www.arc.gov.au/ncgp/lx/lx_default.htm

association with one or more overseas research funding agencies. Access to this funding would require identification of a suitable overseas funding agency and discussion over a considerable period of time with both the ARC and the overseas agency.[31]

- The International Science Linkages program has a competitive grants program for collaborative research and elements targeting collaborations under EU Framework Programs and with France and China.[32] ISL funding could be sought, for example, for proof of principle of technologies for potential use on the ITER machine, working with an ITER party.
- The Australian Academy of Science provides grants for travel to China, Europe, Korea, Japan and the USA.[33]
- The ARC Australian Research Network for Advanced Materials helps students and early career researchers from network participants to travel for between two weeks and six months to other laboratories (nationally and internationally) for collaborative research.[34]
- Marie-Curie Actions, part of EU Framework Program, support mobility of researchers to and from Australia.[35]
- In addition, parties have their own domestic funding arrangements, which in some cases can include funding Australian collaborators.

Collaborations with specific ITER parties

- The Australia-India Strategic Research Fund has a Targeted Allocations component that supports strategic links and relationships between the Australian Government and Indian counterparts. This is not a contestable scheme and open calls are not issued. Fusion-related science and engineering are within the current priority areas of this Fund, which include environment sciences, materials and renewable energy.[36]
- The Australia-Korea Foundation (AKF) promotes links between Australians and Koreans, including in science and technology.[37]
- The AKF, the Australian Academy of Science, the Academy of Technological Sciences and Engineering and the Korea Science and Engineering Foundation support an Early Career S&T Researchers Program. It involves travel to Australia and Korea in alternate years by early career researchers and senior scientists.
- The Group of Eight's Australia Germany Joint Research Cooperation Scheme meets travel and living costs of researchers who spend time at collaborating institutions in Australia or Germany.[38]
- The UK Atomic Energy Authority (UKAEA) offers two-year research fellowships for early career physicists or engineers to work in any field of fusion research conducted at its Culham laboratory. This program encourages overseas placements with

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31 https://sciencegrants.dest.gov.au/isl/Pages/Home.aspx
32 https://sciencegrants.dest.gov.au/isl/Pages/Doc.aspx?name=CompetitiveGrants.htm, https://sciencegrants.dest.gov.au/isl/Pages/Doc.aspx?name=FranceFund.htm and https://sciencegrants.dest.gov.au/isl/Pages/Doc.aspx?name=ChinaFund.htm. This program has supported the Australian fusion community through funding for the 2006 international workshop and, more recently for collaboration between the ANU and Korea.
33 www.science.org.au/internat/programs.htm
34 www.materials.com.au/content/travel_guidelines
35 http://cordis.europa.eu/mariecurie-actions/
36 www.dest.gov.au/science/aisrf
37 www.dfat.gov.au/akf/
38 http://www.go8.edu.au/europe/research/Go8DAADexchange.htm

UKAEA collaborators, which means it could cover placements in Australia as well as giving Australians experience in today's primary fusion research facility in Europe.

Other

- Outreach activities could be supported by the Australian School Innovation in Science, Technology and Mathematics (ASISTM) Project, which aims to increase collaboration between schools and science organisations, universities, business and industry and other organisations; enhance student interest and engagement in the learning of science, technology and mathematics; and increase numbers of senior secondary school students interested in, and participating in science, technology and mathematics. ASISTM funding is directed to school clusters and any such activities would, therefore, be collaborations with such clusters.[39]
- The Supplier Access to Major Projects Global Program funds networks and specialist consultants to work with project developers and Australian industry to increase opportunities for Australian industry to participate in major projects overseas, and to increase Australian industry's access to global supply markets for major projects.[40]

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39 www.asistm.edu.au/asistm/default.asp?id=17207

40 www.industry.gov.au/content/itrinternet/cmscontent.cfm?objectid=2A2AD70F-116A-4EDD-B7D177ABEFC42011&searchID=299404

7. A timetable for action

The Initiative and other actions under this strategy should be introduced incrementally. This would allow the community to demonstrate benefits and to improve the processes involved. It also avoids the problems inherent in large-scale recruitments.

"What are the timeframes?"

This plan is based on a ramping-up of activities, and looks towards an ITER machine contribution being installed in about 10 years.

The timetable for the ITER contribution is on the assumption that the funding would commence from 1 January 2008. A later start would flow on through other dates in this timetable.

2007	Responses sought from wider scientific community
	Negotiations commence for engagement mechanism and benefits to Australia for the Australian ITER machine contribution
2008	Australian Fusion Initiative launched
	Australian Fusion Initiative management and governance arrangements put in place
	Identification of the Australian ITER machine contribution
	Working group for the Australian ITER machine contribution formed, with Australian and international members
	Agreement on scope of, and broad technical specifications for the Australian ITER machine contribution
	Determination of infrastructure required in Australia to support development of the ITER machine contribution
	First call for applications for Australian Fusion Fellows (ongoing in subsequent years)
	First call for infrastructure proposals (ongoing in subsequent years)
	First investment in Australian key infrastructure enhancement (continuing for three years)
	First call for travel and exchange grants (ongoing in subsequent years)
	First annual conference (ongoing in subsequent years)
2009	Agreement on responsibility for costing and IP for the Australian ITER machine contribution
	Formulation of conceptual instrument design, cognisant of all ITER design and technical constraints
2010-11	Construction and testing of prototype diagnostic systems
2011	Australian Fusion Fellowship numbers plateau from this year forward
2011-12	Modelling and detailed design of full-scale ITER machine contribution
2012	Full cost estimate of machine contribution subject to international review
	Call for tenders for construction of the Australian ITER machine contribution
2013-14	Construction of the Australian ITER machine contribution
2014-15	Installation of the Australian ITER machine contribution
2016	Commencement of ITER operations

8. Conclusion

There is an unprecedented opportunity and demand for Australia to increase its investment in fusion-related research, development and education. Opportunity, in the development of ITER and the enormous interest around the world – and notably in Australia – in new technologies that could reduce carbon emissions from energy generation. Demand, in the capabilities that Australia can today offer in the development of fusion energy, and its needs to be equipped to consider adopting fusion energy.

This strategy plan seeks to take advantage of this opportunity and demand, by building capabilities and ensuring that Australia 'stays in the game' through playing a role in ITER. This involves building the skills base – especially given the generational change taking place here in Australia and the lack of employment opportunities for researchers in this nation – and development of a contribution to ITER, and potentially to other global fusion-related systems.

The proposed Initiative brings together skills capabilities, an Australian engagement in ITER and underpinning infrastructure. It aims to bring together diverse – and currently dispersed – activities around Australia, and to more cohesively integrate Australian activities with global programs.

While commercial fusion energy generating systems are decades away, there are strong imperatives to establish an Australian Fusion Initiative *now*. One is that the window to incorporate an Australian diagnostic in the ITER design will only last for one or two years. Another is that many Australian leaders in this area are retiring or have done so, reducing Australia's teaching capacity, international connections and standing, which will affect its absorptive capacity in the long term. A third is that the main substantial research infrastructure for plasma research, the H-1NF, requires additional investment to remain operational in the medium term. A fourth imperative is that developments in the nuclear fission field, notably Australian participation in Generation IV reactors, present an opportunity for a coordinated program including *fusion* research. A fifth imperative is the need to purchase options to address climate change, which is being recognised as presenting this nation with huge challenges over the first half of the 21st century.

This plan emerges from the research community, and its success will depend on that community's commitment. However, it can only be embarked upon with additional investment of public funds. Competitive and leveraged funds will play a vital role, but are not sufficient.

This plan is intended to evolve in line with funding decisions and decisions internationally. The actions and timelines in particular should be reviewed in 2008. That review should be undertaken within the governance arrangements of the Australian Fusion Initiative and the Forum.

Appendix 1: ITER and the path to fusion energy

What does fusion energy offer the world?

Climate change is a major challenge facing the world. One factor is widely considered to be emissions from electricity generation. This has greatly increased interest in the potential of fusion energy, as it offers millions of years of baseload electricity generation with almost no greenhouse gas emissions and very low level radioactive waste, compared to nuclear fission energy and coal burning. Moreover, the main elements used in producing fusion energy are plentiful and widely accessible.

Most conceptual designs for fusion power systems are based on producing one gigawatt of electricity. Fusion could also enable the production of hydrogen, which is seen by many people as an extremely promising energy form, and could be used in water desalination.

Today's nuclear power plants use nuclear fission, but fusion has several advantages over fission, including less radioactivity release in the event of catastrophic systems failure, natural disaster or terrorist attack and an inability to contribute to weapons proliferation.

How will ITER bring us closer to commercially viable fusion energy?

Strong progress has been made over the decades towards viable energy production using fusion.

ITER marks the next step. The goal of the ITER program is "to demonstrate the scientific and technological feasibility of fusion power for peaceful purposes". ITER has dimensions comparable to a power station and will demonstrate or develop all the new technologies required for fusion power stations, except for materials endurance. ITER will be the first experiment in which the heat of the confined products in the plasma will be greater than the external heating. The aim is for ITER to operate up to steady-state conditions producing 10 times as much power as used in its operation.

There is strong reason to be confident that ITER will deliver on its objectives. ITER has been designed by extrapolation from existing experiments, and so the performance uncertainties are as well-researched as reasonably possible; scaling laws have been tested many times on many different devices and the parameters of operation of the world's leading fusion experiment, the Joint European Torus (JET), when scaled to ITER, comfortably exceed those required for ITER's success.

It is envisaged that fusion will become a commercial technology in the second half of this century.

A recent study by Goldston et al[41] estimated the value of the option to build power plants that can produce fusion energy, based on investment in fusion R&D. This analysis indicates that if the probability that fusion will cost less than the best environmentally acceptable alternative for its potential market share is more than a few per cent – either because the best alternative proves to be expensive or because fusion proves to be inexpensive – the option purchased through fusion R&D is "worth it." Choosing not to invest in fusion energy development but to invest the same 80 billion US$2005 would provide insurance against an increase of only 0.0048 to 0.053 US cents per kilowatt hour.

Related programs

The 'Broader Approach', a joint initiative between the European Union and Japan, addresses parallel developments that are designed to accelerate fusion power development, both

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[41] op cit, pp2, 7, 8

during and following the ITER program. The following facilities and programs are being planned:

- A remote experimental control centre as an alternate focus for interaction with ITER
- A virtual plasma modelling laboratory, to bring together models for plasma behaviour on ITER and to make predictions, and later feeding back information from ITER operation
- A ‘satellite’ tokamak providing support (and the ability to rapidly evaluate new ideas) during ITER construction and operation
- The DEMO design team
- A DEMO materials test/qualification facility (IFMIF)

Appendix 2: Australia's record of achievements

1933	While investigating the interactions between positive ion beams and various solids at the Cavendish laboratory, UK, an Australian, Sir Mark Oliphant, and a New Zealander, Lord Rutherford, carried out the first artificial fusion reaction, i.e. they discovered fusion. As a result of their experiment they discovered tritium, the heavy hydrogen isotope, and the helium isotope He3, by bombarding deuterated compounds with deuterons of energies up to 400kV.
1946	An Australian, Peter Thonemann, built and tested the first toroidal magnetic confinement experiment in the UK. Thonemann co-founded the UK fusion program at Harwell in the late 1940s.
1963	Construction of the Liley Torus, at the ANU, the first tokamak outside Russia.
1974	Robert Dewar, while at Princeton, discovered modification to the dispersion relation, caused by mode coupling, of a type which produces some of the key features of Alfvén waves in toroidal confinement devices.
1979	Ieuan Jones, at Flinders University, invented and developed the rotamak configuration.
1980	Construction of the tokamak TORTUS at the University of Sydney. TORTUS operated until 1995 with major programs on Alfvén wave propagation in toroidal geometry (now a major issue for fusion plasma such as ITER's) and coherent scattering diagnostics of plasma waves.
1985	Conceived by an international team, the first heliac confinement device, SHEILA, built at the ANU.
1988	The first demonstration (shared with a German team) of a steady-state spherical torus configuration in a collaboration of Flinders University and ANSTO.
1985 -95	Seven Australians held senior positions at JET, which was the flagship fusion facility. This is especially remarkable as Australia was not formally involved in JET.
1992	The H-1 heliac, the first heliac of sufficient size to approach hot plasma conditions built at the ANU, as a successor to SHEILA.
Last decade	The Turbulence and Transport Studies Group at the ANU transformed fundamental understanding of the crucial ingredient of the physics mechanism of the essential ITER plasma operation mode, the so-called high confinement mode or "H-mode".
	Development of triple-laser interferometer/polarimeter by John Howard at the ANU and Jeroen Rommers of the FOM Instituut voor Plasmafysica Rijnhuizen, which is now used in the US National Spherical Tokamak Experiment.
	The use of micrometer-size dust particles to probe sheath regions where plasma meets a surface
	World's first truly tomographic interferometry system for 2D density imaging operated on the H-1 heliac.
	Advances in theory of plasma vector tomography seed development of patented coherence imaging (CI) systems for high resolution 2D spectroscopic imaging (ANU). Instruments sold to the USA, Korea, Italy and Germany. Spinoff activities with Bluescope Steel Limited.

Appendix 3: Current research and education programs

The Australian research community involved in fusion-relevant science and engineering is spread across nine universities (the ANU, the University of Sydney, the University of Newcastle, the University of Wollongong, the University of Melbourne, Curtin University of Technology, the University of Tasmania, RMIT University, Flinders University), as well as ANSTO. In addition, several other universities and CSIRO have relevant expertise.

Main fusion-relevant programs

The National Plasma Fusion Research Facility at the ANU houses the H-1 Heliac. The Facility is operated by the Plasma Research Laboratory and its mission focuses on:

- Detailed understanding of the behaviour of magnetically confined hot plasma in the heliac configuration
- Development of advanced plasma measurement systems
- Fundamental studies including turbulence and transport in plasma
- Contributing to the global research effort.

The Department of Theoretical Physics at* the *ANU is undertaking research in:

- Computational and visualisation environments
- Complex systems, including convening the ARC Complex Open Systems Research Network, which had as a founding theme the taming of a burning turbulent plasma for peaceful purposes
- Three dimensional magnetohydrodynamics (MHD) equilibrium studies
- MHD spectral studies
- Kinetic theory and transport
- Turbulence modelling
- Wave-particle interactions
- Data grid, storage and mining
- Combustion theory.

The Space Plasma Power and Propulsion Group (SP3) at the ANU is well known for its particle-in-cell numeric simulations. SP3 has an extensive program on low-pressure, high-density plasma physics.

The ANU's and Mt Stromlo Observatory's astrophysics programs have a large plasma physics content.

The ANU's Electronic Materials Engineering team has expertise and infrastructure in the characterisation of materials under extreme conditions.

The ANU's Department of Computer Science has expertise and active research interests in plasma reconstruction, plasma visualisation, data storage and fusion data grids. The Department includes a fusion-relevant case study in software engineering in its e-Science teaching.

The University of Sydney School of Physics is active in plasma physics (laboratory, astrophysical and space theory) and surface materials. It has long experience in developing diagnostic techniques, particularly involving spectroscopy and laser techniques, which contribute to Australia's reputation in plasma diagnostics. The University has an international reputation for its experimental computational and theoretical studies of plasmas containing particulates. A major review of the field has been published recently: Physics and applications of complex plasmas, S.V. Vladimirov, K. Ostrikov, A.A. Samarian, Imperial College Press (London 2005). The University is developing physical concepts for the mechanisms of dust formation, charging and transport in fusion plasma. The University's electrostatic fusion group is making a major contribution to understanding of the operation of inertial electrostatic confinement devices as compact neutron sources. University researchers are collaborating with parties directly involved in ITER, concentrating on the dynamics and transport of dust in the plasma sheath, near walls and in divertor areas; formation and properties of dust; and influence of dust on collective plasma processes. The School of Physics is undertaking research in MAX alloys, which are of great interest for materials that can withstand the high radiation and heat loads that will be present in ITER.

The University also has a significant program in surface modification using radiofrequency discharges and magnetically filtered vacuum arc plasmas, which has relevance to the edge regions and first wall interactions in magnetically confined plasmas. Other research relevant to plasmas is focused on the Sun, heliosphere and magnetospheres.

The University of Newcastle has expertise in surface science and plasma wall interaction as well as particular expertise in high temperature materials. University staff are active in both simulation and experimental research on signatures in materials and have undertaken research in materials similar to those being used in the Garching fusion research facility in Germany.[42] The University's Physics Department is collaborating with the University of Sydney in research on MAX alloys. The University of Newcastle also has interests in space plasma, undertaking experiments in the magnetosphere and ionosphere.

The University of Wollongong has expertise in physical metallurgy of ferrous alloys, welding metallurgy and welding technology, hydrogen embrittlement, structural alloys, creep behaviour, surface engineering and coatings technology. Its teaching program in such areas as physical metallurgy and surface engineering is relevant to fusion materials. The University's materials engineering program can address issues relating specifically to welding and brazing of structural components, radiation and creep damage of structural alloys, and thin film technology for surface engineering. The University is also embarking on a program of work on MAX alloys.

ANSTO is starting new research programs on the materials, design codes and methodologies that are expected to be used in the next generation of baseload power stations. The goal is to create a leading regional facility for measurement and modelling of very high temperature materials behaviour capable of making significant and influential contributions to Generation IV fission reactors, fusion and advanced thermal plant extreme temperature materials. This will be a central plank in Australia's membership of the Generation IV International Forum. ANSTO also has extensive experience in welding science and ceramics.

Curtin University of Technology has an atomic collision group that is undertaking electron-ion interaction research. It has led the formulation and solution of collisions of interest with the long-ranged Coulomb potential and has developed computational theory for the interactions of electrons, atoms and ions of the type likely to be found in fusion and astrophysical plasmas. This team consults to the IAEA regarding its fusion program and is involved in regular IAEA workshops.

The Australian Partnership for Advanced Computing, which provides Australia-wide advanced computing infrastructure for the research community, is involved in a US$12 million US Department of Energy grant to develop a component coupling framework for integrated modelling of core-edge coupled physics in tokamaks.[43]

The Centre of Excellence for Antimatter-Matter Studies (CAMS) is involved in experimental and theoretical atomic and molecular physics, about 10 per cent of which is fusion-related. This centre is located at the ANU, Flinders University, Adelaide University and the University of Western Australia.

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[42] Max-Planck-Institüt für Plasmaphysik (IPP)

[43] This is through Dr Jay Larson who holds a post with Argonne National Laboratory as well as at APAC. Dr Larson is a co-lead investigator on this grant.

Smaller fusion-relevant programs

The University of ***Melbourne*** has a joint appointment with ANSTO held by a materials researcher working on MAX alloys.

RMIT University research in material theoretical simulations is applicable to fusion science.

The University of Tasmania School of Computing undertakes research on rotating magnetic field current drive in confined plasmas.

Flinders University is undertaking research on computational magnetohydrodynamics. Second and third year undergraduate topics on electromagnetism are relevant to fusion.

Potentially relevant programs

The University of New South Wales has relevant ceramics research programs.

CSIRO and the ***University of Western Australia*** have expertise in optics and metrology, which are relevant to diagnostics.

Adelaide and ***La Trobe Universities*** are undertaking experimental research in the ionosphere and atmosphere in support of Australian space plasma interests.

Scale

The following table is not comprehensive but does indicate the relative size of programs at some institutions.

	Number of staff	Full-time equivalents
PRL and Department of Theoretical Physics, ANU	12	10.5
ANU and the Mt Stromlo Observatory's astrophysics programs	~ 30	
CAMS (Number includes students)	35-40	
Complex Plasma Laboratory (CPL), University of Sydney	2	
The University of Newcastle		4
The University of Wollongong	6	3
ANSTO	New program	
The University of Tasmania	1	
Flinders University	1	

The ANU PRL has produced 12 PhD graduates in fusion-related science in the last 10 years, and the Department of Theoretical Physics and has produced at least five in that same period in work relevant to fusion. The University of Sydney produces a comparable number, two PhD graduates just in 2006, for example.

The Universities of Wollongong and Newcastle have produced a significant number of postgraduates in relevant areas of materials over the past 10 years: approximately 30 coming from Wollongong and 17 from Newcastle.

Fusion-focused DEST and ARC grants

Responses to the December 2006 issues paper for this strategy included reference to the following current grants from the Australian Research Council:

- Staff at the Department of Theoretical Physics at the ANU have two current ARC Discovery Project grants worth $860,000 overall and a small ARC Linkage International grant, as well as convening two ARC Research Networks
- SP3 staff have two ARC Discovery Project grants of about $1.2 million, one ARC Linkage grant of about $300,000 and received collaborative funding from AUSPACE of about $240,000 for 2007 for plasma thruster research, and about $100,000 from

the European Space Agency for ion thruster research in 2006

- Staff at the University of Sydney have a Discovery Project grant and a QEII Fellowship investigating dust physics, with specific reference to ITER
- Staff at the University of Sydney, the University of Newcastle and RTWH-Aachen University of Technology in Germany have a Discovery Project grant for research on new alloy phases which also involves the University of Melbourne.

It is not possible to analyse ARC grant statistics to identify other grants related to fusion, due to the diverse and multidisciplinary nature of this research. To illustrate, following are codes from some recent applications, listed in order of frequency

- 240303 – Plasmas and Electrical Discharges
- 291403 – Alloy Materials
- 249903 – Instruments and Techniques
- 291499 – Materials Engineering not elsewhere classified
- 240304 – Other Plasma Physics
- 230113 – Dynamical Systems
- 240202 – Condensed Matter Physics - Structural Properties
- 299999 – Engineering and Technology not elsewhere classified
- 280203 – Image Processing
- 291404 – Ceramics
- 290901 – Electrical Engineering
- 291804 – Nanotechnology
- 280302 – Software Engineering

The same difficulty applies to Socio-Economic Objectives, where the following are among those appear in some recent applications, again listed in order of frequency.

- 670901 – Ceramic
- 680305 – Metals (composites, coatings, bonding, etc.)
- 671499 – Instrumentation not elsewhere classified
- 660199 – Energy transformation not elsewhere classified
- 660104 – Nuclear
- 671699 – Manufactured products not elsewhere classified

In addition, staff at the H-1 National Facility have an International Science Linkages grant for $500,000 fo collaborative studies with General Atomics in San Diego, the National Fusion Research Centre in Korea and the FOM Institute for Plasma Physics in the Netherlands.

International standing

Australian researchers have world-class expertise in plasma physics, the development and analysis of advanced, high heat flux materials and surface science. For example:

- The ANU and the University of Sydney have internationally recognised expertise in advanced diagnostic instrumentation, and have developed concepts that have been applied in instruments that are used in numerous laboratories around the world.
- The Department of Theoretical Physics at the ANU has an international reputation in the development of concepts using magnetohydrodynamics and dynamical systems theory, and sophisticated computational approaches in full 3D geometry. It has also been a leader in the development of sophisticated remote measurement systems for fusion plasma diagnostics and other applications.
- The University of Sydney is making a major contribution to understanding of the operation of inertial electrostatic confinement devices as compact neutron sources. It has an international reputation for its experimental computational and theoretical studies of plasmas containing particulates.

In terms of citations of original Australian research relevant to fusion, the most recognised work has been in the area of experimental tokamak dynamics (the ANU), Alfvén wave heating of tokamak plasmas (the University of Sydney), the rotamak and spherical torus configurations developed at Flinders and ANSTO, MHD and Alfvén wave stability theory (the ANU and Flinders University), helicon wave plasma heating (the ANU), the flexible heliac stellarator configuration (the ANU), plasma turbulence and transport (the ANU), innovative plasma diagnostic techniques and instruments (the ANU and the University of Sydney), plasma surface processing techniques for industry (the ANU and University of Sydney) and novel metallo-ceramic alloys (the University of Newcastle).

Taking four examples of the above:

- Professor Robert Dewar of the ANU has an average of 14.46 citations per item and a Hirsch index of 24.
- For fusion-related research, Professor John O'Connor of the University of Newcastle has an average citation rate of 10 citations per paper and a Hirsch index of 20, over 160 journal papers, 110 conference papers and two books.
- Professor Dewar was elected a Fellow of the American Physical Society in 1980 and a Fellow of the Australian Academy of Science in 1992. Professor O'Connor has held Humboldt and Bede Morris Fellowships.
- Two major research monographs on Alfvén waves have been written by University of Sydney researchers: An introduction to Alfvén waves, Rodney Cross, A. Hilger (Bristol 1988), and The physics of Alfvén waves, Neil F. Cramer, Wiley-VCH (Berlin 2001)

Current editorships include the following:

- Professor Dewar is Divisional Associate Editor for *Physical Review Letters*
- Professor Jeff Harris of the ANU and the Oak Ridge National Laboratory (ORNL), USA is Associate Editor for Plasma Physics of *Physical Review Letters*
- Professor John Howard of the ANU is a member of the editorial board of *Plasma Physics and Controlled Fusion.*

Dr Boyd Blackwell of the ANU is a member of the International Union of Pure and Applied Physics Commission 16: Commission on Plasma Physics – a role that Professor Dewar had earlier held – and the board of the international stellarator advisory committee.

The quality of Australian education and training in this area is evidenced by the large number of graduates from Australian universities working in many of the world's leading fusion-related research facilities, many in senior management positions.[44]

In the 2004 ANU research quality audit, 53% of publications submitted were ranked as exceptionally significant or internationally excellent. In a 2007 survey of citation rates of papers (2001-05) from six toroidal plasma research centres including flagship national institutes and laboratories, the ANU PRL Toroidal Plasma Group had the highest publication rate per author and a citation rate (6.3) second only to IPP and Princeton University Plasma Physics Laboratory (PPPL) (both 8.3).

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44 Some of the better known senior Australian-origin fusion leaders active overseas are David Campbell, Assistant Deputy Director General for Fusion Science and Technology; John How, ITER Project Office; Michael Bell at PPPL; and Alan Turnbull at the École Polytechnique Lausanne and General Atomics.

Other Australian graduates working in Europe include Douglas Bartlett, European Research Directorate; Ben McMillan, École Polytechnique Fédérale de Lausanne; Fenton Glass, Forschungszentrum Jülich; Daniel Andruczyk, IPP, Greifswald; Alex Degeling, IPP, Garching; and Doug Bartlett, JET. Barry Green was until November 2006 based in the EU's energy research directorate.

US examples include Raffi M. Nazikian, Wayne Solomon and Stuart Hudson at Princeton; Ele Andris Dimits, Lawrence Livermore National Laboratory; Dmitri Rudakov at General Atomics, San Diego; George Vahala, College of William and Mary; Sean Dettrick, TriAlpha Energy and University of California, Irvine; Simon Anderson, University of Wisconsin-Madison; and Helen Smith, University of California, Berkeley.

Examples in Asia include Clive Michael, National Institute for Fusion Science, Toki, Japan.

Appendix 4: Take-up of Australian research

The impact of Australian fusion-related research is also evidence of its world-class standing. Examples include the following:

- ANU diagnostics are tools of choice internationally. Coherence imaging systems developed on the H-1NF in recent years represent an alternative approach to 2D imaging of colour scenes via advanced spatial and temporal multiplex methods. High resolution CI cameras developed for plasma temperature and flow imaging have been sold or constructed for installation on the superconducting KSTAR tokamak in Korea, the RFX reversed field pinch in Italy, the W7-X superconducting stellarator in Germany and the JT-60U tokamak in Japan. Such systems and their variants are likely to be implemented on the ITER machine.
- CI systems are also being trialled at Bluescope steel mills in Port Kembla for optical thermography of the molten metal stream issuing from blast furnaces and are being considered for satellite-based earth remote sensing.
- The helicon source, a technology for generation of high-density plasma, was pioneered at the ANU and is now widely used in the microelectronics fabrication industry.
- The helicon-wave plasma source invented and developed at the ANU is used in fundamental and industrial plasma research laboratories around the world
- The helicon double-layer thruster, a derivative of the source technology, is being tested by the European Space Agency as a possible source of thrust for future deep space missions.
- Research at the H-1NF has resulted in several spin-offs in communications, such as the plasma antenna and the BushLAN 'last mile' UHF/VHF wireless internet scheme for remote areas.
- Australian-developed codes (PEST 1, 2 and 3) have been much used in designing new tokamaks, including ITER.
- Australian expertise from the ANU in magnetic fluctuation diagnostics has been taken up in the high frequency Mirnov coil array now used in the Mega Amp Spherical Tokamak (MAST) experiment at the UKAEA Culham facility.
- Novel optical and infra-red imaging spectroscopy techniques invented at the ANU are being adopted in fusion research programs in Europe and adapted for use in the metals industry and medicine.
- The theory of MHD 'ballooning' instabilities – which set the ultimate pressure limits for fusion reactors – and Alfvén wave instabilities rest on fundamental research undertaken at the ANU, Flinders University and the University of Sydney.
- Research at the University of Sydney on plasma processing and modification of materials has produced commercial outcomes in relation to solar selective surfaces, industrial hard coatings and biocompatible surfaces.
- Advanced physical models and experimental data of dust dynamics, transport, charging and dust-plasma interactions developed and obtained in the CPL at the University of Sydney are used by IPP Garching and Groupe de Recherches sur l'Energétique des Milieux Ionisés, University of Orleans.
- ANSTO's Plasma Immersion Ion Implantation (PI^3), a process for hardening metals, has been sold to research laboratories in the UK, Germany, Hungary, Thailand and Singapore as well as to universities within Australia.

Appendix 5: International linkages

Australia has solid links with international research programs that will prove invaluable in ITER engagement. Below are collaborations reported in response to the December 2006 issues paper. They focus on three ITER parties: Japan, the EU and Korea, and are grouped by the Australian and international institutions involved.

Japan

Australian researchers have forged strong links with the Japanese fusion effort. This is evidenced in the following collaborations.

	ANU	**University of Sydney**
General	Triannual Australia–Japan workshops in diagnostics and theory (coordinating role).	
Japan Atomic Energy Agency	• Thomson scattering systems for JT-60U and planned for JT-60SA. • Imaging system for JT-60U planned for February 2008.	
Ministry of Education, Culture, Sports, Science and Technology's National Institute for Fusion Science (NIFS)	• The NIFS was extremely supportive during the establishment of the H-1NF. • A memorandum of understanding (MoU) encompasses the provision of a gyrotron on indefinite loan, technical assistance and exchange visits. • Collaboration on turbulence and transport experiments and modelling and confinement studies in stellarators. • Collaboration on stellarator confinement database studies, also involving the ORNL and Kyoto University.	• CPL exchange visits. • CPL participation in Large Helical Device coordinated research on transport of dust particles in magnetised plasma. • Collaboration with M. Goto on use of collisional radiative model for helium beam diagnostic.
Hiroshima University	Joint development of the pulsed He beam diagnostic installed on the H-1NF in 2006 and used to make the first electron temperature measurements for high temperature operation.	Collaboration on use of helium beams for plasma diagnostics, including laser induced fluorescence.
Kyoto University	• Collaboration with the above and Princeton University, USA, on MHD stability theory and modelling. • Collaboration on comparative stellarator data mining analysis and electron cyclotron heating of plasma in stellarators. • Collaborations with Heliotron-J regarding probes and X-rays. • Also see NIFS, above.	
Yokohama University		Joint publications and exchange visits with the CPL.
Nagoya University		CPL exchange visits.

European Union

	ANU	University of Sydney	University of Wollongong	University of Newcastle
UKAEA	• Agreement to collaborate on research on the MAST experiment and several active collaborations involving the ANU, on mode identification by a Fourier-SVD technique, magnetic coil design, and interpretation of compressional Alfvén Eigenmode activity. • MHD stability theory and modelling.			
IPP (Some aspects also involving CIEMAT, Spain and the University of Maryland, USA)	PRL collaboration on: • The WEGA stellarator • Visible spectroscopy systems for the W7-X stellarator • Quantum chaos in the ideal-MHD spectrum for stellarators • Stellarator confinement database studies. SP3 collaborations.	The CPL has long-term student exchanges, cotutelle programs and produces joint publications.		Ongoing link Initiated.
Institute of Metals and Technology, Slovenia			Surface engineering of titanium alloys.	
Cambridge University, UK			Recent collaboration on creep mechanism in P91 steels.	
RTWH-Aachen University of Technology, Germany, and Linköping University, Sweden		ARC Discovery Project on the simulation and synthesis of MAX-phase alloys.		Part of the project described at left.
Istituto Gas Ionizzati del CNR Consorzio RFX - Associazione EURATOM/ENEA sulla Fusione, in Padua, Italy (also involving IPP, Greifswald and Massachusetts Institute of Technology)	• Department of Computer Science collaboration on plasma databases and remote data access • PRL collaboration on visible			

	spectroscopy systems for its toroidal reversed field pinch experiment. • Spectroscopic imaging diagnostics and edge-plasma studies			
Chalmers University and Institute of Technology, Sweden	Microwave imaging of human breast tissue for cancer detection.			
Politecnico di Torino, Italy; IPP; Laboratorio Nacional de Fusion, Madrid, Spain	Collaboration on turbulence and coherent structures in quasi 2-D plasmas and fluids.			
École Polytechnique Paris	SP3 collaborations and exchanges.			
CNRS-Université de Provence, Marseille, France **University of Naples, Italy** **Rutherford Appleton Laboratory, UK**		The CPL works with a European complex plasma network, with these institutions and IPPs in Garching and Bochum.		
University of Orleans, France		The CPL has long-term student exchanges, cotutelle programs and jointly publishes.		

In addition, and not all of which involve EU members:

- Various arms of CAMS have signed or are signing research collaboration MoUs with Italian institutions
- Switzerland has a long history of hosting Australian postdoctoral researchers at the Centre de Recherche en Physique des Plasmas in Lausanne and of researcher exchange visits
- The ANU and the University of Sydney are popular destinations for engineering and science students from Europe doing a 3-12 month “practica” in research
- There are typically from one to three overseas PhD students doing plasma research at both the ANU and the University of Sydney
- The CLP at the University of Sydney collaborations and jointly publishes with the Institute for High Energy Densities, Russia.

USA

	ANU	University of Sydney	University of Wollongong	University of Newcastle
Princeton University Plasma Physics Laboratory	MoU Collaborations: • On 3D MHD equilibrium and stability • On existence and stability of a model for 3D toroidal plasma equilibria • Involving the ORNL and NIFS on stellarator confinement database studies • Involving PPPL's NCSX stellerator and ORNL (see below).			
ORNL	Former Head of the ANU's PRL, Professor Harris, is based at ORNL on indefinite leave from the ANU and is liaising with a new stellarator project, NCSX, at Princeton.		Hydrogen embrittlement of steels.	
General Atomics in La Jolla, California	• Ergodic divertor experiments. • Electron cyclotron heating of plasma in stellarators • Divertor Doppler imaging using CI systems.			
University of California, Berkeley	SP3 collaborates and exchanges students.			
University of California, San Diego	Collaboration on turbulent structures and transport in plasmas.	CPL collaboration with the Energy Research Center on dust transport in the edge of tokamak plasma.		
Naval Research Laboratory.		CPL collaboration.		
University of Iowa		CPL collaboration.		
West Virginia University	Collaboration on laser-induced fluorescence.			
University of Wisconsin, Madison	• SP3 collaborates and exchanges students • Stellarator			

	confinement database studies (also with ORNL and PPPL).			
Massachusetts Institute of Technology	Collaboration on spectroscopic imaging diagnostics and edge-plasma studies.			
Motorola	Collaboration on plasma switches for mobile phones.			
Lawrence Berkeley National Laboratory		Collaboration on thin film deposition and characterisation and plasma based surface modification.		
Drexel University				Collaboration on high heat flux materials

Republic of Korea

	ANU	CAMS
National Fusion Research Centre	• Design of a diagnostic tool for KSTAR superconducting tokamak. • Membership of the KSTAR International Advisory Committee (Professor Dewar) • Coherence imaging for ion temperature and flow diagnostics in KSTAR tokamak	MoU with Atomic Data Centre to establish a collaboration in the collection of atomic and molecular data which is of relevance to fusion
Korea Basic Science Institute	Spectroscopic imaging diagnostics and edge-plasma studies.	

Additional relationships

Australians also participate in international committees related to fusion, notably the IEA Implementing Agreement on the Stellarator Concept and the International Union on Pure and Applied Physics C16: Commission on Plasma Physics (see Appendix 3).

Australian plasma physics groups have attracted successful plasma physicists from overseas; for example, Heinrich Hora from the Max-Planck Institute in Germany, Sydney Hamberger from the UKAEA and Professor Harris from ORNL in the USA.

Australian educated researchers internationally (see Appendix 3) form an important resource for the research community and industry.

Appendix 6: Australian Fusion Initiative budget

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	**Total**
Fellowships	800,000	1,600,000	2,400,000	3,200,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	**32,000,000**
ITER machine contribution	250,000	500,000	1,000,000	1,000,000	1,000,000	2,000,000	2,000,000	1,000,000	250,000	250,000	**9,250,000**
Key infrastructure enhancement	600,000	600,000	600,000								**1,800,000**
Infrastructure & equipment investment	500,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	**9,500,000**
Key infrastructure operation leveraging	50,000	50,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	**2,500,000**
Travel & exchanges	300,000	400,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	500,000	**4,700,000**
Management	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	300,000	**3,000,000**
Total	**2,800,000**	**4,450,000**	**6,100,000**	**6,300,000**	**7,100,000**	**8,100,000**	**8,100,000**	**7,100,000**	**6,350,000**	**6,350,000**	**62,750,000**

Appendix 7: Development of this strategy

In 2004, the main research teams involved in fusion-related research in Australia came together to form the Australian ITER Forum, to:

- Promote an Australian involvement in ITER and articulate the benefits to Australia
- Promote the science of fusion energy
- Advance the recognition of fusion science and plasma physics in the wider scientific community.

The Forum is supported by nine institutions and covers more than 130 researchers, engineers and specialists in science policy and education.[45]

The Forum organised a two-day international workshop in Sydney in October 2006 that was attended by about 80 international ITER team-members, Australian researchers and representatives of Australian industry and government. The workshop had three key elements: the ITER development program, detailed information on fusion-related research in Australia, and discussion of how the needs of the ITER project and Australian capabilities could be brought together: that is, what Australia might do and by way of which possible avenues of engagement.

Delegates to the workshop agreed that a strategy and business case was needed for engagement in ITER.

Dr Miriam Goodwin of Goodnews Marketing and Communications Pty Ltd was appointed to prepare the plan, which was funded through the ISL grant that had supported the workshop and by AINSE. A working group was formed with Dr Goodwin; the Chair of the Forum, Dr Matthew Hole; the Forum Deputy Chair, Professor John O'Connor, Professor John Howard, Professor Andrew Cheetham from the University of Western Sydney and Dr Dennis Mather from AINSE.

An issues paper was published in December 2006 to elicit further information and comment. Responses were sought by 9 March 2007.

Key directions were set out in a document reviewed initially by the working group and then by the Forum Steering Committee. This document and the issues paper form a large part of this strategy plan. The plan was reviewed by the working group and the Steering Committee before being finalised in August 2007.

Issues paper responses

1. Daniel Andruczyk, Max-Planck Institute for Plasma Physics, Greifswald
2. Australian Academy of Technological Sciences and Engineering
3. Rowena Ball, Mathematical Sciences Institute and Department of Theoretical Physics, ANU
4. Marcela Bilek and David McKenzie, School of Physics, University of Sydney
5. Boyd Blackwell, Plasma Research Laboratory, ANU
6. Rod Boswell, Plasma Research Laboratory, ANU
7. Craig Bowie
8. Igor Bray, Department of Applied Physics, Curtin University of Technology (then at Murdoch University)
9. Stephen Buckman, ARC Centre for Antimatter-Matter Studies, ANU
10. George Collins, ANSTO
11. Alan Costley, ITER Diagnostics Group
12. Robert Dewar, Department of Theoretical Physics, ANU

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[45] See http://www.ainse.edu.au/fusion.html.

13. Rob Elliman, Electronic Materials Engineering Department, ANU
14. Ian Falconer, School of Physics, University of Sydney
15. Henry Gardner, Department of Computer Science, ANU
16. Fenton Glass, FOM Institute for Plasma Physics ‘Rijnhuizen’, The Netherlands on attachment at Forschungszentrum Jülich, Germany
17. Barry Green, then based in the EU’s energy research directorate (now retired)
18. Sydney Hamberger, Research School of Physical Sciences and Engineering, ANU
19. Jeffrey Harris, Fusion Energy Division, Oak Ridge National Laboratory, and Research School of Physical Sciences and Engineering, ANU
20. Matthew Hole, Department of Theoretical Physics, ANU
21. John Howard, Plasma Research Laboratory, ANU
22. Brian James, School of Physics, University of Sydney
23. Erich Kisi, School of Engineering, University of Newcastle
24. Dennis Mather, AINSE
25. David Nolan, Mechanical, Materials and Mechatronic School, Faculty of Engineering, University of Wollongong
26. John O'Connor, School of Mathematical and Physical Sciences, University of Newcastle
27. David Pretty, Plasma Research Laboratory, ANU
28. Horst Punzmann, Plasma Research Laboratory, ANU
29. Michael Scollay, Singtel-Optus Pty Ltd
30. Alex Samarian and Sergei Vladimirov, School of Physics, University of Sydney
31. Julio Soria, Department of Mechanical Engineering, Monash University
32. Robin Storer, School of Chemistry, Physics and Earth Sciences, Flinders University (retired)
33. Richard Tarrant, School of Physics, University of Sydney
34. George Warr, Plasma Research Laboratory, ANU

Glossary

AINSE	Australian Institute of Nuclear Science and Engineering
ASISTM	Australian School Innovation in Science, Technology and Mathematics
ANSTO	Australian Nuclear Science and Technology Organisation
ANU	Australian National University
ARC	Australian Research Council
CI	coherence imaging
CIEMAT	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas
DEST	Department of Education, Science and Training
DEW	Department of Environment and Water Resources
DITR	Department of Industry, Tourism and Resources
EU	European Union
FEAST	Forum for European-Australian Science and Technology Cooperation
H-1NF	H-1 National Facility
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IFMIF	International Fusion Materials Irradiation Facility
IFERC	International Fusion Energy Research Centre
IFRC	International Fusion Research Council
ISL	International Science Linkages
ITPA	International Tokamak Physics Activity
IP	intellectual property
IPP	Institüt für Plasmaphysik
JET	Joint European Torus
LIEF	Linkage Infrastructure, Equipment and Facilities
MAST	Mega Amp Spherical Tokamak
MHD	magnetohydrodynamics
MNRF	Major National Research Facilities
NEA	Nuclear Energy Agency
NRP	National Research Priority
OECD	Organisation for Economic Cooperation and Development
ORNL	Oak Ridge National Laboratory
PMSEIC	Prime Minister's Science, Engineering and Innovation Council
PPPL	Princeton University Plasma Physics Laboratory
QEII	Queen Elizabeth II (fellowships)
RD&E	research, development and education
SP3	Space Plasma Power and Propulsion Unit
UKAEA	UK Atomic Energy Authority