EXECUTIVE SUMMARY

Executive summary

Science and Economic Context

In an increasingly competitive world, the scientific and technological innovations that fuel economic, social and environmental progress for 21st century knowledge-based economies require world class scientific infrastructure.

Scientific techniques and infrastructure are continuously improving, but occasionally breakthroughs occur that enable rapid advances in certain fields. The radio telescope revolutionised astronomy, and the electron microscope and microprobe dramatically transformed research in materials science and geology. Synchrotron technology is having a similar effect, but across many areas of science.

Synchrotron technology is advancing research and development in fields as diverse as:

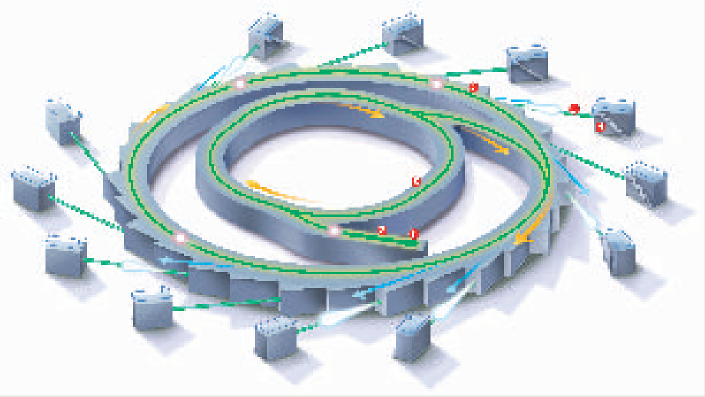
- biosciences (protein crystallography and cell biology)
- medical research (microbiology, disease mechanisms, high resolution imaging and cancer radiation therapy)
- environmental sciences (toxicology, atmospheric research, clean combustion and cleaner industrial production technologies)
- agriculture (plant genomics, soil studies, animal and plant imaging)
- minerals exploration (rapid analysis of drill core samples, comprehensive characterisation of ores for ease of mineral processing)
- advanced materials (nanostructured materials, intelligent polymers, ceramics, light metals and alloys, electronic and magnetic materials)
- engineering (imaging of industrial processes in real time, high resolution imaging of cracks and defects in structures, the operation of catalysts in large chemical engineering processes)
- forensics (identification of suspects from extremely small and dilute samples).

Synchrotron science is advancing rapidly. All major OECD countries have now invested or are investing in synchrotron facilities[1]. Without a world class national synchrotron facility Australia will fall quickly behind its competitors in the capacity to perform leading edge medical, scientific and industrial research.

National Science Case

This document presents the national science case for the initial suite of beamlines that will enable researchers to use light created by the Australian Synchrotron. It is presented by the National Scientific Advisory Committee to the Australian Synchrotron. It aims to provide a framework for consideration by governments, research institutions and industries to support and invest in the establishment of the initial suite of beamlines, which should meet 95% of the anticipated needs of the Australian industrial, scientific and medical research community. This suite of beamlines is essential to undertake the range of experiments critical for achieving economic and social benefits in Australia and in our geopolitical region.

1 Electron Gun **2** Linac **3** Booster Ring
4 Storage Ring **5** Beamlines **6** Experimental Stations



What is a Synchrotron?

A synchrotron is a large machine (about the size of a football field) that accelerates electrons to almost the speed of light, where they have a very high energy level. As the electrons are deflected around the storage ring they give off beams of extremely intense radiation (light) that run tangentially from the machine. These beams are captured in specially designed beamlines and are then used to perform many different types of experiments simultaneously.

1 Lists of world's synchrotron facilities at http://www.spring8.or.jp/ENGLISH/other_sr and at http://www-ssrl.slac.stanford_edu/SR_SOURCES.html

Current Status

The Victorian Government is funding, at a cost of $157.2 million, the construction of the synchrotron machine as the light source required to generate the photons (light) for scientific experimentation, and the building that will house the machine and associated laboratories. In parallel, the National Scientific Advisory Committee has developed the national science case for the initial suite of beamlines. These beamlines are intended to form the experimental hub of the facility.

An International Machine Advisory Committee has been established (see Acknowledgments, page vi) to advise on the design of the machine, and an expert team has been assembled to oversee its construction.

Building work has started and a construction timetable has been established (see chapter 8), with the target date of March 2007 for commencement of operations. The Australian Synchrotron will be a state of the art machine with an energy of 3 GeV and a capacity to provide photons from the infrared region (0.001 eV) to the hard x-ray region (120,000 eV).

The Victorian Government, with the advice of the Australian scientific community, has established broad-based expert National (NSAC) and International (ISAC) Scientific Advisory Committees (see page vi) to the Australian Synchrotron project. These committees have identified the needs of the medical, scientific and industrial research communities and guided the development of this case for an initial suite of beamlines. The aim is to service the majority of Australian synchrotron researchers and their collaborators across a broad range of disciplines, where Australians either currently undertake internationally competitive research or have the potential to do so once a national facility is available. Extensive consultations over the past two years have included an Australian Synchrotron workshop for potential users in January 2003, sponsored by the Victorian Government, and a wide range of workshops and conference sessions, culminating in the preparation of this National Science Case. Australian scientists have received generous expert assistance from their international colleagues in the preparation of this proposal.

The Australian Synchrotron initiative builds on progress already made through the Australian Synchrotron Research Program. This program has been funded since 1996 as part of the Australian Government's Major National Research Facilities Program. The impact of the ASRP on Australia's science and technology has been considerable. The synchrotron user community has experienced major growth (see chapter 5), so much so that limited overseas access is hampering the development of Australian science in several national priority areas. With demand for beam time outstripping supply worldwide, it will become increasingly difficult to meet the needs of Australian research and development using overseas facilities. Furthermore, because of quarantine restrictions, work such as soil science studies and small animal investigations is very difficult to pursue, while the fragile and transient nature of some samples makes long distance travel to other major facilities (all of which are in the northern hemisphere) impractical.

Benefits from Investment in Beamlines

At full capacity, the Australian Synchrotron will be able to accommodate more than 30 beamlines, operating simultaneously and engaging hundreds of scientific and medical researchers, engineers and technologists in the pursuit of scientific discovery and understanding across a broad range of disciplines.

It will be a focal point for interaction among these communities and for enhanced international collaboration. There is an increasing international trend towards large-scale, formalised collaborations, particularly to explore complex medical and biological challenges. These collaborations combine the strengths of major laboratories through research networks, such as the US National Institutes of Health, and Canadian and European equivalents. The Australian Synchrotron will place Australian scientists in a globally competitive position to participate in such large-scale collaborative ventures.

It will have a major impact on the education and research training of the next generation of graduate students, post-doctoral fellows and other emerging researchers in the physical, chemical, materials and biological sciences. Access to such a wide range of the highest quality, state of the art research techniques, together with the opportunity to work in a collaborative community of leading national and international scientists, will enhance the sophistication and breadth of their approach to research.

The Australian Synchrotron will open new opportunities for working across boundaries and in clusters that are linked internationally to world class science. It will assist with attracting and retaining the most talented people. Indeed this is already starting to happen, with lively interest being expressed by world-ranking international scientists, including a number of expatriate Australians.

National Research Priorities

Investment in the Australian Synchrotron beamlines will support the desired outcomes from the four National Research Priority Areas identified by the Australian Government, as outlined in chapter 1.

Synchrotron research will contribute towards building an environmentally sustainable Australia through supporting research in plants and crops, soil science, water and atmosphere pollution, industrial site remediation, mine wastes and fuel improvements.

Synchrotron research is vital to advancing modern medical research, in order to achieve the national priority for promoting and maintaining good health. The synchrotron is an essential tool for drug design, biological research, biotechnology, food sciences and medical imaging, and is showing exciting potential for medical therapy.

The synchrotron is particularly useful in enhancing fundamental research in the basic sciences that underpin the frontier technologies for building and transforming Australian industries. Australian synchrotron research is already contributing to advances in photonics, polymers, ceramics, metals and alloys, bio- and nano-materials, organic and inorganic chemistry, thin film technologies, and advanced manufacturing, particularly in the production of micro-devices.

With regard to safeguarding Australia, the Australian Defence Science and Technology Organisation currently uses synchrotron research for aviation materials testing, and is interested in developing sensor technology. Internationally, synchrotron methods are widely applied in forensic science, and in developing anti-toxins to biological weapons such as anthrax.

The national and international economic benefits of having an Australian facility are outlined in chapter 7.

Industry Engagement

Since its inception the Australian Synchrotron initiative has sought to involve industry and major government agencies such as departments of agriculture and primary industries in the planning of the facility. At the Users' Workshop in January 2003 the following industries and agencies were represented and contributed actively to the decision-making on the choice and specifications of beamlines for the initial suite:

- automotive – three companies
- advanced manufacturing – two companies and one consulting organisation
- scientific equipment – nine companies
- information and communication technology industry – two companies
- food manufacturing – one company and one major research agency
- mining and minerals – two companies
- defence – one company and two research organisations
- health – two pharmaceutical companies, one medical equipment company, two medical imaging and radiotherapy centres, five medical research institutes
- CSIRO – ten divisions.

Since then an active program of seminars and displays at conferences has been held to continue the process of engaging and increasing the number of these commercially oriented potential users. (see appendix 3)

Experience at overseas synchrotrons has been that industry usually accesses synchrotron techniques by collaborating with universities or expert research organisations such as the CSIRO, ANSTO, or DSTO, especially in the early stages while they gain experience and knowledge of the capability of a synchrotron. Accordingly the Victorian Government, in conjunction with ASRP, is sponsoring an industry engagement program with the purpose of ensuring that an active industry/major agency user community is in place when the Australian Synchrotron opens in 2007. Demonstration projects are being supported in the following areas:

- minerals exploration
- manufacturing
- agriculture
- medical science

The industry engagement program will be developed further leading up to the opening of the Australian Synchrotron in 2007. The proposals for industry focussed beamlines (beamline 11 – microdiffraction and fluorescence probe and beamline 13 – lithography) will be facilitated, and industry funding for protein crystallography infrastructure will be sought. The establishment of an x-ray detector centre, with products targeted for general laboratory as well as synchrotron applications, will be encouraged. The program to enable industry access to overseas synchrotron facilities will be expanded nationally, provided funding is made available.

Summary of Benefits

An Australian Synchrotron will assist economic and social development through:

- providing core enabling scientific infrastructure indispensable for building an innovation economy
- stimulating international collaborations and networks vital for the solution of multi-disciplinary globally oriented problems
- facilitating the development of high level scientific and technical skills for the Australian industry
- producing valuable intellectual property to expand Australian and regional capabilities and enhance business competitiveness
- providing industry with ready access to leading edge techniques for R&D, and new insights for advanced industrial processing
- building on and strengthening research and innovation links between Australia and countries in the region
- development of a multi-disciplinary user community leading to interchange of ideas and experimental techniques.

Table 1. Recommended initial suite of beamlines for the Australian Synchrotron

No	Beamline Description	Category	Energy Range
	Crystallography & Diffraction		
1	High-throughput Protein Crystallography	A	2–23 keV
2	Protein Microcrystal & Small Molecule X-ray Diffraction	A	5.5–20 keV
3	Powder X-ray Diffraction	A	4–60 keV
4	Small and Wide Angle X-ray Scattering	A	5.5–20 keV
	Spectroscopy		
5	X-ray Absorption Spectroscopy	A	4–65 keV
6	Soft X-ray Spectroscopy	A	0.1–2.5 keV
7	Vacuum Ultraviolet (VUV)	B	10–350 eV
8	Infrared Spectroscopy	A	0.001–1 eV
9	Microspectroscopy (submicron-XAS, XANES, & XRF)	A	5–20 keV
	Imaging		
10	Imaging & Medical Therapy	A, B	10–120 keV
11	Microdiffraction and Fluorescence Probe (XRD & XRF mapping)	C	4–37 keV
	Polarimetry		
12	Circular Dichroism	B	2–10 eV
	Advanced Manufacturing		
13	Lithography	C	2–25 keV

A Proposed Initial Suite of Beamlines

The National Scientific Advisory Committee to the Australian Synchrotron and the International Scientific Advisory Committee recommend consideration of the establishment of a suite of up to thirteen beamlines in the first few years of the facility's 30-year life.

The thirteen recommended beamlines have been grouped into three categories, as summarised in table 1. An outline of each of these experimental facilities is presented in chapter 10.

Category A

There are nine general purpose beamlines considered essential to be available or under construction at the commissioning of the synchrotron in 2007. This suite provides a comprehensive range of techniques that will meet most of the scientific, medical and industrial research needs. Preliminary cost estimates for these nine beamlines total to approximately $A49.5m.

Category B

Two beamlines (VUV and circular dichroism) are considered highly desirable for a balanced set of capabilities for the synchrotron; however the experienced user communities for these lines are small and will require time to develop. In addition, beamline 10 (imaging and medical therapy) can be extended for large-scale imaging and beamline 1 can be further developed. Preliminary cost estimates for these beamlines and modifications total $A14.9m, and consideration of funding for these will be sought separately after the Category A beamlines are established.

Category C

Two beamlines (microdiffraction and fluorescence probe and lithography) are principally for industrial and commercial use. Preliminary cost estimates for these are $A3.4m for the microdiffraction and fluorescence probe and $A4.2m for the lithography beamline. A separate funding plan is being developed for these beamlines based upon a combination of direct capital contributions and cost recovery fee-for-service policy.

Management Framework and Access Policy

It is the view of the National Scientific Advisory Committee that the synchrotron should be managed as a national facility consistent with the principles established for other major research facilities. There are several mechanisms by which this outcome may be achieved. While one approach is examined in chapter 9, a decision must await further discussions amongst the parties that invest in the facility. It will be essential for the achievement of breakthrough scientific outcomes that the facility is managed to the highest international standards. An outward view is vital to ensure that, in addition to local synchrotron users, some of the world's leading synchrotron scientists are attracted to the Australian facility.

It is proposed that access to Category A and B beamlines will be on a merit basis – consistent with the ASRP process developed by the Australian Government and with well-established access models used at other international facilities. Access guidelines would be established through peer review mechanisms to support the scientific management team at the synchrotron. It is anticipated that there would be the close involvement of the research funding agencies in this process.

Also consistent with international practice, overall access arrangements would facilitate priority to industry users, generally on a cost-recovery basis.

Under the proposed model, a proportion of the time available for scientific experimentation on these beamlines would be reserved for members of funding agencies and institutions that have invested in the capital funding of the Category A and B beamlines. Access would still be merit based and would be additional to any beam time sourced from the general pool.

It will be important to ensure that access arrangements enable researchers from across the country and New Zealand to have the same opportunity to participate in synchrotron research as their colleagues located in Melbourne. The ASRP and AINSE programs provide useful models for this.

Operating Costs

The annual operating costs of a synchrotron comprise the fixed costs to maintain and operate the machine and associated infrastructure as a leading edge facility and costs associated directly with the number of operating beamlines. The development and finalisation with key stakeholders of the coverage of operating costs and the methods by which these are met will be important elements of future stakeholder discussions. Further details are provided in chapter 4.

Beamline Funding Proposal

Following an extensive consultation process, the National Scientific Advisory Committee recommends on behalf of the Australian scientific and industrial user community:

- that the nine general access beamlines identified in this proposal be jointly funded in a partnership involving research institutions, State and other governments and industry, with the Australian Government. Details of the matching basis to be finalised in future discussions
- that two general access beamlines (beamlines 7 and 12) plus an extension of beamline 10 be funded when additional capital funds become available
- that usage guarantees and direct capital contributions be sought from industry to enable the construction of a microdiffraction and fluorescence probe and a lithography beamline, with these two beamlines being operated on a predominately fee-for-service, cost recovery (including capital) basis, once fully operational.