

2016 National Research Infrastructure Roadmap

Capability Issues Paper

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Questions

Question 1: Are there other capability areas that should be considered?

As per the Physics Decadal Plan: Extensive consultation with the community conducted by sub-discipline working groups identified three broad areas of opportunity for the future of Physics in Australia. These are: (i) the New Quantum Revolution; (ii) The Quest for New Physics and New Symmetries; and (iii) Physics in the Society in which we live.

With regard to (i): At present there is no specific capability area that specifically addresses the infrastructure for the quantum revolution; however the infrastructure presently employed is dispersed in some of the other capability areas. This has been a significant factor in supporting Australian leadership in this field.

With regard to (ii): With the recent discovery of gravitational waves and the strong Australian involvement, the incorporation of observatory upgrades and the development of new observational techniques involving fundamental physics research in the field of quantum optics and pulsar astronomy will need to be developed. Also the field of dark matter research is likely to develop rapidly over the next decade. Given the benefits of establishing a dark matter research laboratory in the southern hemisphere and the close to ideal location of the proposed Stawell mine dark matter observatory, this is a capability that, with further development, could have significant impact. Some of the technologies that support the development of new observational techniques will arise from the opportunities that emerge from the new quantum technologies, as already has been the case for the quantum optics used for gravity wave detection.

One especially acute area, that is heavily contested, is the need to address the challenges of climate change and to meet the associated, ambitious CO2 emission reduction targets with locally developed innovations. As has been pointed out by Kelly (M.J. Kelly, Lessons from technology development for energy and sustainability, MRS Energy & Sustainability: A Review Journal, doi:10.1557/mre.2016.3) having well qualified personnel and up to date information is essential. At present there is no explicit NRI capability in this area although Australia has many relevant elements in various present areas of infrastructure and existing activities. It is now necessary to determine if this model is still appropriate or if a more specific capability must be identified. This could be in the areas of electricity and power, transport, efficiency, etc.

Question 2: Are these governance characteristics appropriate and are there other factors that should be considered for optimal governance for national research infrastructure.

The list of governance characteristics provided in the issues paper cover both inputs (such as user access and IP management issues) and some outputs (such as skills, training, benefits and outcomes).

To achieve higher impact for better target NRI funding, there should be several additional considerations to guide the governance of the facility. These are:

- *Potential for international leadership in the capability area. An example of this attribute is the involvement of Australian laboratories in the development of the quantum optics for gravity wave detection and the quantum computation and communication effort. In the past the development of the fast Fourier transform chip now at the heart of WiFi technology could fit into this category, but the leadership may have been difficult to assess in advance.*
- *Potential to seed major new initiatives and spin-out enterprises. Examples here include the “BluGlass” semiconductor commercialisation initiative, “Redfern Photonics”, “QuintessenceLabs” for quantum security, “Moglabs” for specialised optical products and others. Also the governing principles could include the principle of supporting major Australian research consortia with a demonstrated critical mass and impact such as ARC Centres of Excellence which have an ambitious research program and can capitalise on the support provided by NRI.*
- *Potential for involvement of Australian Industry could also be listed in the governance principles. This can be direct as in the conduct of collaborative research projects of direct relevance to the market. It can also arise from the involvement of Australian Universities in major international consortia where partnerships in such consortia open the possibility of Australian companies bidding to provide goods and services to the consortia as a result of the partnership agreement. Full membership in CERN would be an example of the latter where the proposed accelerator upgrades could utilise equipment manufactured in Australia.*

Question 3: Should national research infrastructure investment assist with access to international facilities?

This should be a significant feature of NRI-supported laboratories in the field of Physics because strong engagement with the international Physics community enhances Australia’s research capability and relevance. This occurs by technology transfer by the exchange of people and also participation in collaborative research projects.

Mechanisms to allow Australian physicists to continue to test their ideas and collaborate with international teams at experimental facilities (such as the Large Hadron Collider at CERN and the LIGO facilities) and work on new international projects (such as the Square Kilometre Array) must be preserved and further developed. See also the list of collaborations under Question 22 below.

Question 4: What are the conditions or scenarios where access to international facilities should be prioritised over developing national facilities?

As has been well established with the precedents of developing major research infrastructure beyond the means of a single country, there are many advantages to Australia being a partner in off-shore facilities.

At the top tier of scale and cost are the particle physics accelerators and astronomical observatories. These include the next stage of the experimental particle physics research program beyond the capabilities of CERN and the full development of the Square Kilometre Array. There are also projects where the development of networks of highly interconnected laboratories are appropriate such as the emerging global network of gravitational wave observatories, dark matter laboratories, observatories for climate science (including the very important Cape Grim observatory in Tasmania) and others.

At the next tier of the scale are the international research networks where research groups in Australia, some of which are supported by existing NRI facilities, provide specialised expertise of relevance to those international networks. These include expertise in nano-scale materials processing, various photonic technologies, renewable energy technology, and the expanding field of quantum technology. These areas may also have near-term relevance to Australian commercial activities. Examples are local sensor and imaging developments in the medical, environmental and defence applications. The recent launch of the EU Quantum Manifesto proposes an ambitious program of research and development supported by a network of European and international laboratories where Australia could contribute and gain access to advanced research capability from a network much bigger than could be established in Australia. Access to this network could be supported by an NRI scheme that specifically supported international research linkages.

Question 5: Should research workforce skills be considered a research infrastructure issue?

In many cases in our peer laboratories globally the key components of the technical infrastructure are supported by PhD qualified technical staff. They play a significant role in the maintenance and development of the facility as well as training of users. The dependence on short term soft money to support these facilities make it difficult to maintain a well-qualified support staff and a globally competitive facility. Therefore research workforce skills are a significant research infrastructure issue. In fact the appropriate research support staff are necessary to provide the maximum return on the infrastructure investment.

As an example, the Australian Synchrotron supports users with qualified beamline scientists to ensure the facilities are applied to maximum benefit to the projects that make use of the beam time. It should be possible to integrate this into the NRI scheme.

Question 6: How can national research infrastructure assist in training and skills development?

The training of research higher degree students must be a fundamental requirement of NRI supported laboratories. The role of the scientifically trained professional, with a Masters or PhD in science and role in academia, commerce and industry will be essential to harness all the future technology developments supported by NRI for the benefit of Australia.

The emphasis on the skill-base will differ to some extent between the different domains of employment. However the scale and impact of large research facilities provide a richer environment than would be possible in a research group within a University or government laboratory. Examples include:

- *Training in the development and access to Intellectual Property that could be relevant to potential commercial spin-offs.*
- *Development of expertise in the conduct of research, the applications of research and the ability and skill to carry out advanced data analysis and modelling in the context of multi-disciplinary professional teams that can address more challenging and important problems beyond the scale of a single institution*
- *Access to researchers with complementary skills and expertise that can give individuals a wider exposure than would be possible in their home institution.*

Question 7: What responsibility should research institutions have in supporting the development of infrastructure ready researchers and technical specialists?

This should be a major role for the NRI supported research institutions. It should be the responsibility of the NRI supported facility to work with the researchers' home institution to provide these benefits:

- *Participation in a research program that may include a period of international collaboration;*
- *Skill development as an independent researcher;*
- *Capacity to apply sophisticated mathematical and computational methods to solve a wide range of physical problems, including highly abstract fundamental issues and complex technological and engineering challenges;*
- *Recognition of the potential for wide-ranging, international inter-disciplinary collaboration in which the methods of physics are applied to chemical, biological, environmental, technological, engineering, finance and defence problems;*
- *Willingness to take a leading role in the application of the experimental , mathematical, computational, analytical and conceptual methods of physics to address complex issues currently facing society;*
- *Develop experience with collaborative approaches to the solution of complex physical problems that recognizes the international character of research in physics.*

Question 8: What principles should be applied for access to national research infrastructure, and are there situations when these should not apply?

The access principles should not discourage use of the facilities for projects with high potential or new projects that do not yet have a track record and may be high risk. Access principles that balance the potential to raise revenue from users with the potential for high scientific returns need to be developed. Facilities with a well-established system for allocating resources to users could be used as a model for this purpose. These include the Australian Synchrotron and the OPAL reactor.

In common with some major international facilities, such as the Hubble Space Telescope, the Director could be allocated time for special initiatives that do not need a rigorous evaluation process. This would also act as an incentive for the recruitment of an appropriate Director of the facility.

Question 9: What should the criteria and funding arrangements for defunding or decommissioning look like?

Major facilities should have an independent governing board that reviews the performance of the facility on a regular basis, for example every five years. Review of the performance of the previous term and goals for the next term could be established at these reviews. A case should also be made for continuation of the NRI support at these reviews. In some ways the NRI facility is like an ARC Centre of Excellence, however on a larger scale and with a focus on serving external users. The proposal for funding renewal and the evaluation of impact could be done in a similar way.

However if the decision is made to decommission the facility there will need to be facility-specific plans made. In general these plans will include the redevelopment of the facility into a new capability area that makes use of as much of the existing infrastructure as possible. Models for how major infrastructure has been repurposed exist in cognate laboratories world-wide. For example the Lawrence Berkeley Laboratory successfully made several major changes of focus over the past few decades. Also the Stanford Linear Accelerator Centre transitioned from a fundamental particle physics laboratory to a free electron laser facility which may provide a suitable model for how this can be achieved.

Question 10: What financing models should the Government consider to support investment in national research infrastructure?

This is a very challenging issue for research infrastructure that needs careful consideration. Examination of successful strategies from peer laboratories around the world should be conducted with a view of adapting these models to the Australian context.

At the same time, it would be necessary to examine the significant difference between Australia and OECD peer countries which is the small proportion of private sector investment in physics research. As Australia makes the transition to the post-resource-based economy, suitable incentives to redress this imbalance need to be developed.

The provision and resourcing of national research infrastructure is an ongoing challenge because of the strong competition from well-resourced laboratories overseas. For example Australia's capability for many aspects of quantum technology are world leading at present. However initiatives in the UK, Europe and Canada in this area will make it difficult to maintain this leadership in the near future without more investment. Hence a financing model needs to incorporate the ongoing development of the facility to keep up with international peers in areas of the strategic priority areas in effect at the time of the review of the facilities.

Question 11: When should capabilities be expected to address standard and accreditation requirements?

It is important that such requirements should not consume resources that would otherwise be directed to research. A 5 year cycle of review and accreditation would be appropriate. The process should maximise use of the standard research metrics including ERA and the associated impact statements and not develop independent processes that would be expensive to implement.

In the case of accreditation required for servicing the needs of commercial partners, the associated costs should be carried by the customer.

Question 12: Are there international or global models that represent best practice for national research infrastructure that could be considered?

There are a large number of different practices in this area. Given the complexity of the landscape, it would be worth having a working group examine standard practices in our OECD peers. There are several models that would be worth examining:

- *The Fraunhofer, Leibnitz and Helmholtz Institutes in Germany that perform directed research, manage specialised laboratories and manage large research infrastructure on behalf of external users respectively.*
- *The LETI laboratory in Grenoble that provides access to advanced prototyping and measurement facilities through its Minatec Centre.*
- *The major international research consortia dedicated to specialised research projects including CERN and LIGO.*
- *The existing major laboratories in Australia including the Australian Synchrotron, the OPAL reactor and possibly also the CSIRO animal health laboratory.*

Question 13: In considering whole of life investment including decommissioning or defunding for national research infrastructure are there examples domestic or international that should be examined?

As cited above, there are examples where major laboratories have made the transition to new purposes. In the case of major research infrastructure, both physical and human, the process of transition is more appropriate in this context than decommissioning because decommissioning would not capture the prior investment. There are numerous examples that should be examined:

International

- *SLAC particle physics to free electron laser*
- *Lawrence Berkeley Laboratory bevatron to Advanced Light Source*
- *Harwell, UK*
- *Mt Wilson observatory, USA*
- *Munich research reactor to neutron irradiation cancer therapy*
- *French CEA to renewable energy research*

Australia

- *NICTA phase out*
- *Photonics CRC¹ to ARC CoE*
- *Others...*

Not all of these examples necessarily show best practice, but serve as guidance for better transitions in the future.

¹ <http://www.aphref.aph.gov.au-house-committee-scin-pathways-subs-sub23.pdf>

Question 14: Are there alternative financing options, including international models that the Government could consider to support investment in national research infrastructure?

See response to question 10.

Health and Medical Sciences

Question 17: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Health and Medical Sciences capability area?

The development of a physics-intensive facility for hadron therapy has been cited in other submissions and this is an initiative of interest to the NCP. The development of such a facility in Australia should be done in conjunction with experts in the field of physics and medicine.

Advanced Physics, Chemistry, Mathematics and Materials

Question 21: Are the identified emerging directions and research infrastructure capabilities for Advanced Physics, Chemistry, Mathematics and Materials right? Are there any missing or additional needed?

Following a process conducted at the Australian National University in August 2016, several capability areas were identified that would be of benefit to Australian researchers. Many of these missing capabilities could be provided by enhancements of existing NRI capabilities. Others require further coordination before they could be considered for NRI support. Here is a summary of the missing and additional needs identified by this process. Facilities specifically for research in astronomy are not included here.

- *There is presently no clear process for the development of new beamlines on the Australian Synchrotron and the OPAL reactor. There is already strong support from potential user groups for these developments to occur.*
- *Access to international facilities by funded-membership was identified as an important funding model for Australian researchers. Such access often involves knowledge transfer or Australian contributions to equipment design and development. Funding of the GMT serves as a local example of how such membership can return major benefits to Australian researchers and the broader community.*
- *National Ultra-High-Field Nuclear Magnetic Resonance (NMR) Capability. Recent advances in nuclear magnetic resonance (NMR) spectroscopy have taken magnetic field strengths to over 23 Tesla (1 GigaHertz frequency). Such spectrometers are of particular use for protein structure determination. Australia does not have a spectrometer of this size or capability and at a cost of around \$20m it is difficult to fund such an instrument from non-NRI sources.*
- *Virtual National Photovoltaic Laboratory to support cross institutional access to existing infrastructure and ongoing photovoltaic technology development in Australia.*
- *Enhanced cryo electron microscopy and crystallography capability. Recent advances in these areas have opened up many possibilities for protein structure elucidation at the atomic level.*

Such microscopes are very expensive (\$10-15m) to buy and to run. Their capabilities would fit into the NRI envelope.

- *Foundry for the custom design and fabrication of microelectronic devices and test structures. Such a facility is beyond the budget of NRI but the research needs of Australian scientists and engineers could be met through negotiated access to national or international custom foundries (e.g. Silanna Pty Ltd).*
- *Support for the Stawell Underground Physics Laboratory. This laboratory represents a partnership between government, education and industry with a focus on the search for the unidentified dark matter, the development of ultra-sensitive radiation measurement instrumentation, environmental science, health, biology, geology, mining and deep sub-surface life. It is currently funded by the State Government of Victoria and the Federal Government together with additional support from ANSTO, and national and international university partners.*
- *Related to the point above and the submission to be made by AMMRF the consultation document flags the need to coordinate the development of precision instrumentation which originates from either National Capabilities directly (Astronomy), or is derived from engagement with Capabilities (ANFF/AMMRF).*

Question 22: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Many researchers in this capability area rely heavily on access to unique and complementary equipment and infrastructure around the world. As such there is strong support for NRI-funded access programs. The nature of the access arrangements will clearly vary from facility to facility but it is important that such schemes are flexible and responsive. (i.e. they need to be able to fund access to core facilities with relatively short lead times.)

Examples of facilities and infrastructure include:

- *ITER (International Thermonuclear Experimental Reactor)*
- *Synchrotrons (ILL Grenoble, Argonne, Pohang, Skuba, etc)*
- *Ion Accelerator/ Nuclear Physics Facilities*
- *GANIL, France,*
- *ISOLDE-CERN, Switzerland,*
- *RIKEN, Japan,*
- *FAIR/GSI, Germany,*
- *FRIB/NSCL (National Superconducting Cyclotron Laboratory), USA*
- *TRIUMF, Canada,*
- *Jyvaskyla Cyclotron, Finland*
- *ELI-NP (Extreme Light Infrastructure Nuclear Physics), Romania*
- *EuroBioImaging/Synchrotron*

There are many opportunities for Australian researchers to engage with new and emerging research programs, both as collaborators and/or full partners. The benefits from such engagement are multi-faceted but generally include access to new infrastructure and associated skills and expertise. However, this often requires some level of co-investment. NRI support for such engagement would be appropriate but would need to be assessed on a case-by-case basis.

Selected examples of major international research programs include:

- Horizon 2020-Europe, see <https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020>
- The BRAIN Initiative –USA, see <http://www.braininitiative.nih.gov/>
- Human Brain project –Europe, see <https://www.humanbrainproject.eu/>
- European Quantum Technology Flagship <https://ec.europa.eu/digital-single-market/en/blog/entering-preparatory-phase-towards-quantum-technology-flagship>

Question 23: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Advanced Physics, Chemistry, Mathematics and Materials capability area?

The alignment of LIEF with NRI needs to be considered. There are many examples of LIEF funded equipment being under-utilized due to a lack of appropriate technical support and infrastructure. This could be addressed by encouraging alignment between LIEF and NRI. This could also promote the alignment of new capabilities with identified new and emerging research directions.

There is also currently a gap in funding between LIEF (typically <\$1M) and NRI (which is best used for major facilities costing >\$10M). The \$1M to \$10M range includes both NRI-worthy national research infrastructure and equipment that is more appropriately dealt with by LIEF (items that are for limited purposes or have less than national reach, but are of high scientific merit). Increasing the effective upper range of funding for LIEF and having some overlap in scale between LIEF and NRI would address this issue.

Access to national research infrastructure (imaging, characterization, fabrication, analysis tools, etc.) is also an important issue, and needs to be appropriately funded to maximise the effectiveness of the NRI investment. (i.e. re-instate travel and access program for users and trainers to access NRI facilities). There are a number of cross-disciplinary research infrastructures that could provide very significant and broad benefits, but which lack the focussed support of some of the more discipline-specific infrastructure.

If you believe that there are issues not addressed in this Issues Paper or the associated questions, please provide your comments under this heading noting the overall 20 page limit of submissions.

The Physics Decadal Plan process identified very strong support for the introduction of an international science linkages scheme to support Australian researchers to join major international consortia with access to research infrastructure too expensive to develop in Australia. Present schemes are too slow to deliver the necessary near-term funds for this purpose.

Another important issue identified in the Physics Decadal Plan process is the challenge of recruiting and retaining human capital within a highly competitive global marketplace. The impact of NRI capability areas could be enhanced with strategic initiatives to attract individuals or research groups to Australia to employ the infrastructure for new research projects that address important problems of international significance. With the right candidates, successful initiatives could have a significant impact on the development of new industries, the training of qualified personnel including PhD students and postdocs and the lifting of Australian universities in the international rankings and hence the recruitment of international students.