Submission
2016 National Research Infrastructure Roadmap
Capability Issues Paper

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Questions

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

(1) Proposal for a Centre for Radiation Research, Education and Training (CRRET)

SA is currently undertaking and discussing a number of strategic projects related to radiation use, and analysis. These include the SA Copper Strategy and more recently the findings of the SA Nuclear Fuel Cycle Royal Commission (NFCRC). Through the University of Adelaide, and other universities and a number of large industry partners, a multimillion dollar ARC Transformational Industry Hub grant (the Cu-U Hub) is being coordinated. A new proposal to set up at Copper Hydrometallurgy Facility located at the Tonsley precinct has recently been proposed. This facility is proposed to include a radionuclide analytical facility for Copper processing. The recent findings of the NFCRC suggested that a Centre of Excellence should be established if SA is to proceed further into the nuclear fuel cycle.

As a result of the increased interest in radiation use and analysis, an infrastructure capability and education gap exists in the area of applied radiation research and education and training. There is also a gap in the provision of analytical services for commercial gain with most services provided interstate.

Currently, there are multiple areas of high-quality radiation expertise which exists in SA, however it is spread widely and not focussed on delivering specific radiation outcomes. Recently, a number of stakeholders came together to discuss a proposed CRRET. Stakeholders which have demonstrated interest include the University of Adelaide, Flinders University, the University of South Australia, the SA Environment Protection Authority, SA Museum, CSIRO, mining industry partners and the SAHMRI. All of the stakeholders recognised the growing capability gap in areas of major and rising economic importance.

Stakeholders agreed that a high priority to target this capability gap is the creation of a multi-institutional CRRET; a CRRET will contribute significantly into each of Health and Medical Sciences, Environment and Natural Resource Management, and Advanced Physics, Chemistry, Mathematics and Materials capabilities. A CRRET will also allow for the provision of commercial services such radionuclide analysis to a range of stakeholders.

Key opportunities exist in areas of low dose radiobiology, mining and mineral processing, the nuclear fuel cycle and radiation education and training, including nuclear engineering, environmental science, chemistry, medicine, and radiation management.

International collaborations currently exist and will be developed further in alignment with Australian needs and IAEA plans for the future, in areas including radioactive waste disposal, food and water safety, radon strategies, low dose medical exposures, occupational and environmental protection, and radiation education and training.

Mining and mineral processing of uranium ores and other radionuclide-bearing minerals depend critically on understanding the nature of radiation damage in radioactive and non-radioactive minerals. Currently, the limited knowledge of mineral radiation damage is a major impediment to economic extraction of these valuable resources.

Low dose radiobiology research is currently only undertaken at Flinders University in Australia. Additionally, research is urgently needed with regard to effects of new PET isotopes, low dose medical procedures and radon exposure, and for environmental monitoring and radiation impact on biota.

Allied areas including radiation biology, novel medical imaging tracers, nuclear forensics and radioanalytical heritage chemistry are variously impeded by the infrastructure capability gap and would greatly benefit from a national collaborative approach.

Developing geobiological (bacterial) controls on the dissolution and precipitation of radionuclides may prove of great importance in the management of nuclear waste sites and understanding the cycling of radionuclides in the environment. In addition, the ability to trace nuclear wastes in the environment using technologies such as Atom Trap Trace Analysis will important.

A CRRET having both substantial measurement capacity and embedded specialist expertise would meet the increasing demand from industry for radiation analytical services, and be positioned to respond to the potential opportunities for education and training being created by ongoing events, notably the conclusions of the SA Nuclear Fuel Cycle Royal Commission.

(2) A national ultra-low background underground laboratory facility

We believe, and strongly support, the collaboration led by the University of Melbourne, that has recommended there should be an additional category for underground laboratories for fundamental and applied science. Relevant research currently being undertaken within Australia includes dark matter searches and nuclear activity screening. Fundamental in the global search for dark matter is the requirement of an underground facility in the southern hemisphere.

Stemming from the construction of a national ultra-low background underground laboratory facility, many new areas of study can be pursued in the physical, astronomical, material, and life sciences. For many of these applications the background cosmic radiation at sea level or above is not optimal for carrying out experimental work. A facility deep underground (more than 800 m) provides a “ultra-low-background radiation” facility, making it perfect to house sensitive experiments such as dark matter direct detection (a current emerging direction), as well as future projects in neutrino-physics, geophysics (muon tomography), materials science (high purity materials and purification systems), and astrobiology.

(3) Fourier Transform Infra-Red (FTIR) spectroscopy and imaging

The University of Adelaide has recently established a new laboratory for complex carbohydrate analysis, ‘Adelaide Glycomics’, in collaboration with the company Agilent Technologies Australia Pty Ltd. This Partner Laboratory offers a comprehensive series of approaches for the fine characterisation of the most abundant and complex molecules on earth, but also the lead understood. Complementary to this initiative, Agilent Technologies together with key national players in spectroscopy, including The University of Adelaide, aims to establish a Network of Excellence of high relevance to Australia in the specific area of FTIR-based chemical imaging through the NCRIS scheme. The partners envisaged for the initial phase of this national Network of Excellence are:

1. The University of Adelaide through 'Adelaide Glycomics' for the chemical imaging of carbohydrates in biological tissues, single cells and materials, with applications in the biomedical sciences, agriculture, microbiology, food and nutrition, and biomaterials;
2. The University of Queensland Translational Research Institute, with focus on cancer research and development of rapid pathology fingerprinting techniques;
3. The University of Western Australia with applications in agricultural biotechnology and rapid protein assays;
4. The University of Melbourne and Metabolomics Australia for research in agricultural biotechnology and root zone assays;
5. The Florey Institute with focus on neurodegenerative diseases and rapid analysis of related pathways;
6. The University of Newcastle for research in remediation of the environment and contamination assessment;
7. Monash University for studies of drug interactions with human (cancer and red blood) cells.

FTIR chemical imaging delivers exceptional spatial resolution at the micrometre scale, together with reliability, performance, reproducibility and user friendliness. It is based on the detection of vibrational, rotational and other low-frequency modes of molecular components subjected to infrared irradiation to provide a fingerprint by which structural differences can be identified within individual samples or across samples of the same type. It can be used for instance to identify phenotypic differences between mutant and wild-type cells, analyse the local composition of subcellular structures, tissues and materials.

It is anticipated that The University of Adelaide would play a key role in assisting the uptake of FTIR Spectroscopy into the Life Sciences as an orthogonal approach to enable research with an emphasis on rapid and spatially selective assays. Support through the NCRIS Scheme would greatly facilitate the deployment of a FTIR Spectroscopy Imaging platform across Australia in concert with Agilent R&D engagement and a collegiate approach across the cohort of the abovementioned Academic members.

(4) Food Research

Infrastructure capabilities for food research (both plant and animal) needs greater emphasis than currently outlined in the issues paper. Australia's continued position as a net food (& wine) exporter of high quality and well-managed goods will need strong investment in underpinning capabilities such as advanced genomics, phenomics and processing.

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

Governance should have a TOR including powers to facilitate national level consistency, e.g. for Human and Animal Ethics. We should also consider a national/central oversight of critical shared infrastructure/services to ensure equitable and sustainable operation of the facility, as well as equitable and sustainable costs to end users.

Governance models need to continue the robust KPIs and metrics from the original NCRIS, including the explicit intention for the broadest possible availability and access for researchers. As the research infrastructure "ecosystem" across Australia continues to strengthen and evolve, there should be greater expectation on cognate capabilities to cooperatively align efforts to achieve the dual aims of enhancing services and minimising unnecessary competition between capabilities. In addition, more work is needed to manage the tension in interests between capability user(s) and capability owner(s), when these are sometimes the same organisation(s). An administering or 'owning' organisation should have the same (no greater) rights to the services provided by a capability than any other research user. Finally, IP and moral rights should not be unnecessarily encumbered simply by virtue of use of an infrastructure capability.

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

Yes, in strategic priority areas. The University supports national research infrastructure investment to assist in the development of superior international facilities, particularly where Australia is not able to afford to have the equipment. For example, equipment that bone and joint researchers need but cannot access nationally includes very powerful MRI (at least 15T) to explore bone, cartilage, muscle, tendon, etc. tissues in small animals with high resolution. There is such a device in Vanderbilt in Nashville, which has high skilled physics specialists managing it. Infrastructure support toward this device would allow access, but should also include the costs to transport scientists and specimens to the site, as these costs are rarely allowed in grants.

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

The above example would save significant capital and recurring labour and maintenance costs locally, whilst enhancing the capabilities at the international site to the benefit of all users. The types of facilities best suited to this arrangement are those with significant costs for acquisition and operation, where local researchers do not need to visit regularly. It is of no value for applications that need regular or real time access.

The focus should be on major international capabilities with equitably distributed benefits to participating nations; or areas of major strategic benefit to Australia which can't be achieved in isolation.

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

Yes – this is an obvious oversight where there is little/no support from funding agencies to build workforce skills especially in the areas of biostatistics and informatics. These are not the same fields however. Major science journals (Nature, Science) are full of the papers describing issues of poor reproducibility, poor methodology and poor statistical technique. Our research workforce both established and developing must do better in this area of science.

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

Training and skills development can be supported through merit access schemes with a focus on ECRs, as well as development of suitable and appropriate training modules/courses in the use and application of the capability. This will require direct funding of training and up-skilling programs where researchers can gain/improve their skills in these areas. Current opportunities for such up-skilling are idiosyncratic and opportunistic. They need to be systematic and have agreed quality control standards. An example is a researcher in need of extra training for more than basic bio-statistical knowledge in Australia. It is not clear where this researcher could go. Some funding could be provided to such candidates to identify appropriate courses, and some level of standardisation and accreditation needs to be included.

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

The primary responsibility, but supported with availability of training and development programs at relevant national capabilities.

Should there be a shift to more centralised and specialised large scale centres of expertise for infrastructure, this will require co-investment from this initiative and institutes, and the necessary skilled operators are the responsibility of the institutes to train, but in a coordinated and accredited manner as referred to above in 6.

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

Broadest access at minimal cost to academic research community, based on principles of need, merit and equity. Industry/private sector users should be able to access an upper defined %, but at suitable fee-for-service levels. The principles of merit-based public-sector Australian research; merit-based or partial cost recovery based public-sector international research; and the private sector at partial or full cost recovery as stated are appropriate. As the research focus shifts to a more interdisciplinary nature including public sector service providers and industry, the access should be based on scientific merit, but with a cost structure that reflects the ability to pay for such access.

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

At the initiation of a new infrastructure implementation, commitments must be made on the expected duration of service of the infrastructure, and a mandated development of business modelling 2-3yrs prior to the end of life of the infrastructure. This modelling, together with annual reviews on utility/sustainability and outputs will inform the research community of the commitment to replace or retire the services. This will allow appropriate planning of research and minimise wastage/reduced outputs. It also facilitates better planning of skilled research workforce members.

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

The financial model must include whole of life costs, with clear strategies to cover the acquisition/maintenance and operation of the infrastructure for its full planned life. Cost recovery models should be used, but these must be projected well in advance to allow users to seek funds to support access. It must also align with funding models for bodies such as NHMRC/ARC and MRFF to allow such direct research costs to be included in grant budgets and not cut.

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

When industry provide funding to the capability to address and maintain such requirements. However, this should probably be a standard requirement for any infrastructure initiative. Without this, the reliability/utility of the infrastructure is compromised. When industry provide funding to the capability to address and maintain such requirements.

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

The EU Research Infrastructures program would seem to have many salient lessons for Australia (refer http://ec.europa.eu/research/infrastructures/index_en.cfm).

Their May 2016 report - http://ec.europa.eu/research/infrastructures/pdf/lts_report_062016_final.pdf#view=fit&pagemode=none includes consideration of the matters raised by Questions 9 & 10 above, and questions 13 & 14 below.

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?

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

Health and Medical Sciences

Question 15: Are the identified emerging directions and research infrastructure capabilities for Health and Medical Sciences right? Are there any missing or additional needed?

The section describing "5.2.5 National health and medical data capability" is not representative. There could be some perceived bias by only naming two facilities and we are aware that there have been some service quality issues in relation to one of these facilities. These types of assets have high potential value and have funded successful data linkage agencies in SA-NT, however, investments in Qld and Vic have not delivered significant new capacity in those states. The other facility has been excellent but risks being overtaken by newer technologies and it has significant cost pressures. As a consequence costs to end users are becoming unsustainable. We will need smarter solutions than re-creating storage and analytics environments when universities and MRIs already have this infrastructure. We need to move toward a more collaborative mindset if we are to successfully address some of these issues.

Similarly, there has been a history of biobank initiatives that have seeded excellent facilities that then close through a lack of funding to operate, and limited resources being available to contribute from researcher grants, again, as a result of inconsistencies in the grant funding allowances and cuts to budgets in projects and programs.

Imaging infrastructure is fragmented and dispersed randomly though the country dependent largely on individual institutions' ability to build funds and manage the infrastructure. Development of coordinated service provision with nodes of infrastructure dispersed to meet the needs locally should be a focus.

Food and nutrition is one area that should be added to the emerging trends. Food plays an essential role to human health, both in developed countries, where obesity, diabetes and heart disease are a major health concern, and in the developing world, where malnutrition, nutrient and vitamin deficiencies cause millions of deaths each year. Malnutrition is estimated to cost the global economy US$3.5 trillion per year (FAO, 2014). On 1 April 2016, the United Nations General Assembly agreed a resolution proclaiming the UN Decade of Action on Nutrition from 2016 to 2025 (http://www.who.int/nutrition/GA_decade_action/en/; Appendix C). Agriculture forms part of the action plan, by producing nutritious and healthy food. Functional food, such as high-fibre barley or high-iron rice and wheat can help tackle the underlying causes, before medical intervention is required.

Question 16: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Yes. The model of the Farr Institute in the UK. It sits within a consortia of universities run collaboratively by providers (e.g., government) and users (e.g., researchers). This model is a way of fostering intelligent use of administrative data for public good.

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?

Environment and Natural Resource Management

Question 18: Are the identified emerging directions and research infrastructure capabilities for Environment and Natural Resource Management right? Are there any missing or additional needed?

Many of the greatest challenges facing humanity over the next decades are environmental in nature – climate change, loss of plants, animals, microbes and ecosystem services, emerging pathogens, and management of fisheries, forests and agriculture. Solving these challenges will require environmental scientists to be able to tackle increasingly complex problems with big data. We are moving towards parameter estimation and asking "how much" and in "what direction" ecosystem processes are affected by different mechanisms. High-value data on the environment such as essential living and biophysical attributes, land uses, human populations, health and welfare and their emergent properties are critical to government.

Most of the large environmental issues we will face are national or international in scope – to answer them we need data collected in standard ways across the whole continent, not just localised research areas. The Terrestrial Ecosystem Network (TERN) is addressing this, but more needs to be done. We also need compatible, consistent and accurate integrated ecological plot data – Without which we're unable to answer the big questions mentioned above. Again – TERN Enables this.

Question 19: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

The Australian Plant Phenomics Facility (APPF) has been a partner in the European Plant Phenotyping Network (EPPN), as the only non-European facility. In addition, there is also the International Plant Phenotyping Network (IPPN), of which APPF is a member. IPPN was formally launched last year and there are different working groups under development with relevance to Australia.

Question 20: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Environment and Natural Resource Management capability area?

Agriculture is a key industry to the Australian economy, especially in the export market, where agricultural commodities were worth $44B in 2014, with $6B for wheat alone (DFAT, 2016). Viticulture and oenology are examples of fields severely lacking in major national research infrastructure investment for many years. With the mining boom contracting, it is in the national interest that Australia takes advantage of the emerging 'dining boom' in the Asia-Pacific region and demand for high-quality and highly nutritious food and wine. To capitalise on Australia's competitive advantage and tackle the sustainable production challenges we face through environmental; change, we need to support agriculture with access to the best research infrastructure.

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?

Nuclear science and energy are very much on the agenda (e.g. the current SA Royal Commission). Australia is eminently positioned as a major nuclear minerals resource, and there would be significant opportunities for collaboration between universities, government agencies and industry. There is an opportunity to develop Nuclear & Radiation Science capabilities covering:

- Nuclear Chemistry
- Nuclear Engineering
- Mineral Processing and Hydrometallurgy
- Radiation Safety

A **'smart exploration hub'**, with technologies to identify explorative areas under cover, technologies to focus on resource targets, and technologies to efficiently delineate and exploit the resource whilst reducing waste and environmental impact. Links beautifully with the Australian Academy of Science's UNCOVER initiative. The hub would combine drilling technology and exploration geology with innovative ways of investigating the origin of the Australian mineral-hosting basement, through magnetotelluric imaging (see below), low temperature thermochronology, isotopic mapping, distal regolith/cover footprints and structural permeability, and ways of processing complex ores.

Magneto-telluric Imaging: Phase 2 of the AusLAMP project is one of the six highest priority areas identified by the UNCOVER industry roadmap. Phase 2 would develop higher density 3D arrays in key terrains. Innovations will be (a) in production of world-class and world-leading data sets for industry; (b) innovations in technologies in terms of building cheap instrumentation that can be used in Australia and worldwide (could be a large market for the right products); (c) in providing work for many geophysical contractors; & (d) employment in software and services as a high technology area.

Photo-catalysis centre of synthesis labs, clean rooms or assembly glove-boxes and solar simulators to develop nanostructured materials from excess (waste) mineral resources and to use these as catalysts and photocatalysts for fuels. The aim would be to work in partnership with minerals industry to develop new value-added materials that function as catalysts. The centre would build the foundation infrastructure to take the developed technology to the prototype stage for industrial use. It would be a dedicated facility to construct and test photocatalytic systems with capacity to scale-up to commercial levels, in partnership.

Next generation 3D printing/Additive manufacturing beyond metals - printing optical quality glass (preforms for optical fibre, laser substrates, with the hybrid materials in 7.1.2, scale up of size of facilities under 7.2.2 e.g. the ability to make larger preforms for optical fibre manufacture enabling more structures to be formed in fibres hence the ability to make new sensors and fibres with novel properties. A new Nanoparticle fabrication facility under 7.3.2 would be really valuable.

A **photonics prototyping/packing facility** able to cheaply develop field deployable photonics prototypes would be of great value to both researchers, start-ups and more established companies. Key skills / capabilities include photonics engineering, product engineering, design, electronics, software, mechanical engineering. A recent Photonics Roadmap for South Australia identified this as a key gap.

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

Gravitational waves detection.

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?

Understanding Cultures and Communities

Question 24: Are the identified emerging directions and research infrastructure capabilities for Understanding Cultures and Communities right? Are there any missing or additional needed?

There needs to be more emphasis on Social Sciences infrastructure in this section of the NRIC framework. The current emphasis is on Arts and Humanities infrastructure without much thought to needs of economics, geography, sociology, psychology, anthropology and political science. All they get in this document seems to be a 'network' of unspecified form and function.

At the quantitative, big-data end of the spectrum, social scientists need better publicly funded infrastructure linking, harmonizing and making accessible the widest possible range of social science datasets. These are currently collected and kept in very fragmented, feudal ways. Government data labs with interlinked social science data do exist but they are kept under lock and key for legitimate privacy reasons. Public investment is needed to make largescale, harmonized social science datasets securely available to a wider range of research communities. Following open data access models of institutions like the World Bank and IPUMS would be helpful.

At the other end of the spectrum there is a need to think more innovatively about how public infrastructure enables the *qualitative* research at the core of UCC research. The framework attends to facilities like libraries, archives, and collections which safeguard materials of historical and cultural significance – again this is an arts and humanities focus rather than a social science one. A 'network' could potentially help in this area but it's hard to tell how without more detail on what this would actually look like.

More fundamental is the role of government in providing Open Access to published, publicly funded research. UCC research relies particularly heavily on the analysis and interpretation of texts, and social scientists tend to work mainly with recently published scholarship. They are particularly hard hit by the model of academic publishing that prices libraries and other research organizations out of access to publicly funded research publications. The need for open access publishing infrastructure is an issue well beyond the UCC area, but it is in the UCC area that it bites particularly deeply.

Question 25: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 26: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Understanding Cultures and Communities capability area?

National Security

Question 27: Are the identified emerging directions and research infrastructure capabilities for National Security right? Are there any missing or additional needed?

Food security should be added to the emerging capability needs as an adjunct to biosecurity. While Australia is one of the more food-secure nations, we should be working to ensure we avoid food production shortages and their associated political and economic impacts.

Question 28: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

The Cyber Security CRC will be seeking to develop and host a **national cyber range** should the CRC be successful. One of the objectives would be to link this national cyber range internationally to a major capability in the US. Two things: (1) a national cyber range is vital nationally; and (2) if we could define critical research infrastructure to include the staffing cost, then we should do so because that will be the dominating cost. The problem for this, and much networking research, is that testbeds and other infrastructure are important, but relatively low cost but testbeds require a lot of maintenance, setup and management to enable others to use it effectively.

Question 29: Is there anything else that needs to be included or considered in the 2016 Roadmap for the National Security capability area?

Underpinning Research Infrastructure

Question 30: Are the identified emerging directions and research infrastructure capabilities for Underpinning Research Infrastructure right? Are there any missing or additional needed?

Question 31: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

Question 32: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Underpinning Research Infrastructure capability area?

Data for Research and Discoverability

Question 33 Are the identified emerging directions and research infrastructure capabilities for Data for Research and Discoverability right? Are there any missing or additional needed?

Interoperability of systems – need broad, ontology-based data management such as that used in TERN's AEKOS. For a data exchange approach to be successful it has to be efficient and flexible. It must cope with the increasing volume and complexity of data generated by rapidly advancing technology. This makes data storage a minor consideration compared with extensibility and portability of data management processes. Most importantly, improvements in computing technology continue to generate new approaches to harnessing semantic information contained within data collections, and to promoting new strategies for knowledge management. Ontology-based data management is a modern solution yet many database systems of NCRIS capabilities use relational "flat file" structures – yesterday's technology. Data ontologies record the metadata for data items used in a specific information domain – they are unique to their domain/subdomain. Ontologies have been built for many domains (chemistry, powder diffraction, molecular biology). A world-first for the environment is TERN's innovative AEKOS which is a research grade version yet to reach its full potential and be commercialised.

Development of standard, domain dictionaries for easy finding of data and its related information. For example, discoverability is of little value if the data cannot be used intelligently and in some cases not accessible.

Academic rewards for publishing data openly and transparently in terms of methods, data authors, institutional and funding acknowledgements and opportunities for new collaborations

Adoption of the globally agreed **Findability Accessibility, Interoperability Reproducibility (FAIR)** principles for repurposing of open scientific data

A culture of sufficient data curation and its peer review. **Investment in data cultural shifts** and training in ontological data management system is critical. Surviving data records (including sensor records) are often incomplete and unusable because of the lack or scant metadata for intelligible reuse. While data archiving should have improved in the electronic age, in some areas it has deteriorated because of the high turnover rate of storage media with rapidly changing technology. The ability to access knowledge is an essential requirement of any field, and this makes the efficient exchange of information of fundamental importance if it is to deliver national benefits. This is widely appreciated, but the definition and expression of electronic data remain poorly coordinated in science. This poses major obstacles to efficient data interoperability.

Question 34: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

- International Council for Science: Committee on Data for Science and Technology
- DataONE

Question 35: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Data for Research and Discoverability capability area?

Other comments

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 Roadmap should be more clearly aligned with National Science and Research Priorities. Such an approach would also facilitate identification of common requirements across priority research areas for larger scale investment. This could also serve to inform other sources of infrastructure and research investment through research organisations, who are often contributing operating support, and the competitive funding agencies. Improved co-ordination of investment at all levels – landmark infrastructure, local infrastructure, operational support and related funding for project support - is likely to be more effective in achieving national objectives in research.