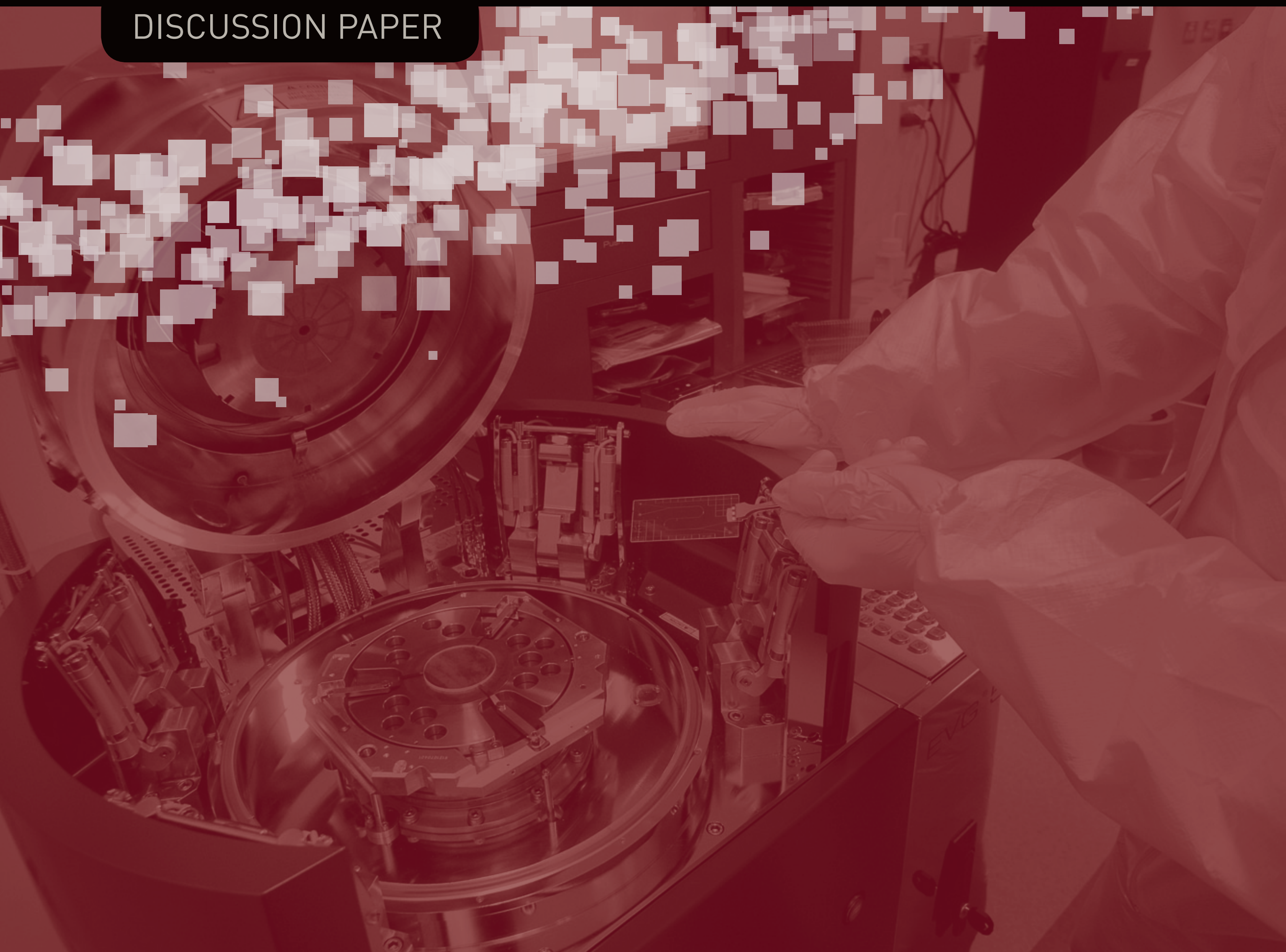
Australian Government

Department of Innovation
Industry, Science and Research

2011 STRATEGIC ROADMAP FOR AUSTRALIAN RESEARCH INFRASTRUCTURE

DISCUSSION PAPER



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This document, released in March 2011, does not necessarily represent the views of the Department of Innovation, Industry, Science and Research. It is a discussion paper only, and should not be construed as necessarily representing elements to be included in the 2011 Roadmap.

Introduction

The Department of Innovation, Industry, Science and Research (DIISR) is developing a *2011 Strategic Roadmap for Australian Research Infrastructure* (2011 Roadmap), which will articulate Australia's national research infrastructure priority areas (Capability areas). The 2011 Roadmap will inform future decisions on where Australia should make strategic infrastructure investments to further develop its research capacity and improve research outcomes over the next five to ten years.

The 2011 Roadmap will aim to consider new or emerging areas of research which may require different types of infrastructure in the future, and determine whether the current mix of Capability areas continues to meet researchers' needs. The 2011 Roadmap will consider priorities in an international context, reflecting the international, collaborative nature of modern research and the important role of collaborative research infrastructure in bringing researchers together.

Two previous Roadmaps for Australian Research Infrastructure have been developed. The first was released in 2006[1] as part of the implementation of the National Collaborative Research Infrastructure Strategy (NCRIS)[2]. The second, the *2008 Strategic Roadmap for Australian Research Infrastructure,*[3] built on the 2006 Roadmap and presented a renewed view of the priority areas for strategic research infrastructure investments. The 2008 Roadmap formed the basis for the Australian Government's 2009 Super Science Initiative[4].

The 2011 Roadmap will once again focus on Capability areas, and as such it will not aim to identify specific items of infrastructure, or evaluate current funded facilities in each of the Capability areas. The 2011 Roadmap should identify areas where public investment in research infrastructure will make a significant difference to Australia's research and innovation outcomes.

At the same time as this Roadmap is being developed, the National Research Infrastructure Council (NRIC)[5] is finalising a *Strategic Framework for Research Infrastructure Investment*. It is intended the Strategic Framework will provide a high-level policy framework, which will include principles to guide the development of policy advice and the design of programs related to the funding of research infrastructure by the Australian Government.

Roadmapping has been identified in the Strategic Framework Discussion Paper[6] as the most appropriate prioritisation mechanism for national, collaborative research infrastructure. The strategic identification of Capability areas through a consultative roadmapping process was also validated in the report of the 2010 NCRIS Evaluation[7].

[1] http://ncris.innovation.gov.au/Documents/2006_Roadmap.pdf
[2] http://www.innovation.gov.au/Science/ResearchInfrastructure/Pages/NCRIS.aspx
[3] http://ncris.innovation.gov.au/Documents/2008_Roadmap.pdf
[4] http://www.innovation.gov.au/Science/ResearchInfrastructure/Pages/SuperScience.aspx
[5] http://www.innovation.gov.au/Science/ResearchInfrastructure/Pages/NRIC.aspx
[6] http://www.innovation.gov.au/Science/ResearchInfrastructure/Pages/NRIC.aspx
[7] http://www.innovation.gov.au/Science/ResearchInfrastructure/Pages/NCRIS.aspx

The 2011 Roadmap is primarily concerned with medium to large-scale research infrastructure. However, any landmark infrastructure (typically involving an investment in excess of $100 million over five years from the Australian Government) requirements identified in this process will be noted.

NRIC has also developed a ‘Process to identify and prioritise Australian Government landmark research infrastructure investments’ which is currently under consideration by the government as part of broader deliberations relating to research infrastructure.

NRIC will have strategic oversight of the development of the 2011 Roadmap as part of its overall policy view of research infrastructure.

2011 Roadmap Process

A key aspect of the roadmapping process is the use of Expert Working Groups to provide specialist advice to the department on developments in research and priorities for research infrastructure.

Six Expert Working Groups have been established using the National Research Priorities (NRPs)[8] as an organising principle, with additional groups for ‘Understanding Cultures and Communities’ and ‘eResearch Infrastructure’. The eResearch Infrastructure group will specifically consider the underpinning, pervasive ICT infrastructure requirements needed to support all research and research collaboration.

The six Expert Working Groups are as follows:

- Environmentally Sustainable Australia
- Frontier Technologies
- Safeguarding Australia
- Promoting and Maintaining Good Health
- Understanding Cultures and Communities
- eResearch Infrastructure

The department sought nominations from a wide range of stakeholders in late 2010 and received more than 400 nominations. Members of these groups have been drawn from a wide range of discipline areas and institutions, and have been selected on the basis of their skills and knowledge in specific areas, and their ability to engage with and seek views of their peers and other stakeholders. A list of members is included at **Attachment A**.

The roadmapping process has been designed to allow for the widest possible consultation.

Following analysis of responses to this Discussion Paper, an Exposure Draft Roadmap will be developed and released for further consultation in June 2011. The final *2011 Strategic Roadmap for Australian Research Infrastructure* will then

[8] http://www.innovation.gov.au/AboutUs/KeyPublications/PortfolioFactSheets/Documents/NATIONAL-RESEARCH-PRIORITIES.pdf

be provided to the Minister for Innovation, Industry, Science and Research to inform any future government consideration of investment in research infrastructure.

An indicative timeline for the process is shown below:

Late March 2011	Discussion Paper released for public comment
Late March – Mid April	Expert Working Groups to consult with stakeholders
4 May 2011	Closing date for comments on Discussion Paper
Early June 2011	Exposure Draft Roadmap released for public comment
Early July 2011	Closing date for comments on Exposure Draft Roadmap
August 2011	Final Roadmap presented to Minister

Purpose of this Discussion Paper

The purpose of the Discussion Paper is to seek comment from the wider research community on the views expressed by the Expert Working Groups, and to canvass additional feedback on Australia's priority research areas and the infrastructure requirements to support excellent, innovative research into the future.

The Discussion Paper contains six chapters that set out each Expert Working Group's perspective on key topics relating to future research infrastructure priorities. These include the group's views on strategic developments, emerging trends or changing focuses in specific areas of research (both nationally and internationally) and the Capability areas that may be required in the future to support excellent, innovative research.

It also contains general reflections on the Capability areas described in the previous Roadmaps and whether the current investments remain an appropriate and adequate response to those Capability areas. These observations are put forward as a starting point for broader consultation and responses from stakeholders. A list of funded research infrastructure facilities is provided at **Attachment B** and brief descriptions of national, collaborative research infrastructure capabilities being implemented through NCRIS and Super Science are at **Attachment C.**

In addition, the paper highlights fundamental and underpinning Capability areas and eResearch infrastructure required to support cross-discipline and multi-disciplinary research. It is important to note that not all research infrastructure is specific to a particular discipline or NRP and ensuring these Capability areas are identified and appropriately prioritised is a key concern in the roadmapping process.

The first four chapters in the Discussion Paper begin with an outline of the relevant NRP in order to provide some scope for the chapter, notwithstanding the close relationships between elements of several NRPs.

However, this approach to structuring the paper risks losing the critical connections between the NRPs themselves, and across the entire research sector.

For example, significant change resulting from research in the Promoting and Maintaining Good Health and the Environmentally Sustainable Australia NRPs will, to a large extent, be enabled by a multi-disciplinary approach, with researchers from natural and social sciences, and the humanities working together.

Thus, while we have established a separate Expert Working Group ‘Understanding Cultures and Communities’, it is important not to lose sight of the role that research in Humanities, Arts and Social Sciences disciplines plays in the translation, implementation and transformation of research across the NRPs.

Research Infrastructure policy issues

In addition to the discussion in each Expert Working Group’s chapter, there are several issues that concern all of the groups and relate to the design of research infrastructure funding programs more generally. These are being considered by NRIC in its development of the *Strategic Framework for Research Infrastructure Investment*.

Rather than address them in detail in each chapter, they are canvassed briefly here, not to seek feedback from stakeholders, but to indicate that they are understood, and are being addressed by NRIC.

Operating costs

The need to be able to fund the ongoing operation of research infrastructure has been identified in responses to NRIC’s Strategic Framework Discussion Paper and in many of the Expert Working Groups’ deliberations to date.

Many responses indicated that, ideally, future research infrastructure funding programs should be able to support all aspects of research infrastructure including capital costs, skilled technical support staff, operations, maintenance and effective governance of facilities.

Some Expert Working Groups also raised a need for a marketing and business development capability for national collaborative research infrastructure facilities, to enable the provision of a ‘one-stop shop’ to the wider research community and industry.

Pricing/access

Several Expert Working Groups identified access and pricing as important factors influencing uptake of research infrastructure.

Responses to NRIC’s Strategic Framework Discussion Paper indicated that access and pricing regimes should be clear and transparent. Stakeholders also indicated that competitive access for finite research infrastructure resources should be based on a combination of factors including merit, co-investment, the role of the host institution, opportunities for early career researchers, and supporting collaborative research.

Comments also suggested that, in addition to research infrastructure at the national and landmark scale being made widely accessible to publicly funded researchers on the basis of merit and other factors, local or institutional research infrastructure should be made accessible to the extent possible in order to maximise use and support collaboration between institutions.

Excellence

The Strategic Framework Discussion Paper, in the section on prioritising research infrastructure investment, made the following observation:

> Australia should prioritise investments in research infrastructure to ensure the needs of the nation and its best researchers are met. This means prioritising investment based on excellent research, or areas in which Australia seeks to develop leading research capability. Any consideration of research excellence also needs to be balanced by a focus on innovation outcomes and the contribution that research makes to productivity and prosperity[9].

Since that discussion paper was released, the Australian Research Council (ARC) has released the Excellence for Research in Australia 2010 National Report[10].

In its overview of that report, the ARC noted that Australia performed ‘well above world standard’ (i.e. received a rating of five across four or more institutions at the four-digit discipline level) across the following disciplines:

> Cardiovascular Medicine and Haematology; Oncology and Carcinogenesis; Immunology; Medical Physiology; Human Movement and Sports Science; Clinical Sciences; Pharmacology and Pharmaceutical Sciences; Astronomical and Space Sciences; Quantum Physics; Optical Physics; Plant Biology; Evolutionary Biology; Ecology; Zoology; Geology; Historical

[9] http://www.innovation.gov.au/Science/ResearchInfrastructure/Documents/Strategic%20Framework%20for%20Research%20Infrastructure%20Investment%20-%20Discussion%20Paper.pdf

[10] http://www.arc.gov.au/pdf/ERA_report.pdf

Studies; Electrical and Electronic Engineering; Macromolecular and Materials Chemistry; and Physical and Structural Chemistry[11].

This objective assessment will be helpful in future discussions about which areas of research Australia excels in, and the extent to which future national research infrastructure programs should ensure those disciplines are supported.

Integration of existing and future facilities

Several Expert Working Groups have discussed whether the next stage in national, collaborative research infrastructure should be to build on the existing funded projects not only in extending the infrastructure they provide, but also in integrating currently separate facilities to form a broader, coherent capability or set of services.

This is a theme that has emerged through discussion, in particular, in the Environmentally Sustainable Australia group, and in the Frontier Technologies group. In part, it arises from a desire to bring together elements of existing capabilities, such as Characterisation and Fabrication or the Terrestrial Ecosystem Research Network, the Integrated Marine Observing System and the Atlas of Living Australia. It is also motivated by a desire to simplify some of the governance and access arrangements that have built up around NCRIS and Super Science as the programs have been implemented.

Consultation

Your feedback is sought on the themes and issues canvassed in the Discussion Paper. You may choose to comment on the entire paper or on particular chapters, and questions are included in each chapter to help draw out your views and focus responses.

Your feedback can be formal (for example, an official institutional submission) or informal (for example, a few sentences in an email).

Responses to this Discussion Paper will be used by the Expert Working Groups and the department to help refine existing Capability areas identified in previous Roadmaps, and to define potential new Capability areas for inclusion in the 2011 Roadmap.

Responses to the Discussion Paper will be made public on the Department of Innovation, Industry, Science and Research website. **Please indicate when you send your response if you do not want it to be made public.**

Responses to the Discussion Paper should be sent to the Department of Innovation, Industry, Science and Research electronically (preferred) by **COB Wednesday, 4 May 2011.**

[11] http://www.arc.gov.au/pdf/ERA_2010_national_fact.pdf

If you have any questions, these should be directed to the Roadmap team at the contact details below.

Contact Details

Email: Roadmap2011@innovation.gov.au

Address: 2011 Roadmap
Research Infrastructure and Science Policy Branch
Department of Innovation, Industry, Science and Research (DIISR)
GPO Box 9839
CANBERRA ACT 2601

Phone: (02) 6213 6375

Environmentally Sustainable Australia Expert Working Group

The *Environmentally Sustainable Australia* National Research Priority (NRP) is aimed at transforming the way we utilise our land, water, mineral and energy resources through a better understanding of human and environmental systems and the use of new technologies.

This NRP has seven priority goals: Water – a critical resource; Transforming existing industries; Overcoming soil loss, salinity and acidity; Reducing and capturing emissions in transport and energy generation; Sustainable use of Australia's biodiversity; Developing deep earth resources; Responding to climate change and variability.

National and global challenges continue to be high priority drivers for environmental innovation and research in Australia – food, water, resource and biological security; the impacts of increasing human population, resource use and climate change on environmental systems; and reduction of greenhouse gas emissions through development of renewable energy. The extreme weather and climate events of 2011 have reinforced the significant impact of climate variability and change on Australia. The inter-relatedness and complexity of these challenges increasingly demand a 'systems approach' to research and the development of research capability, including infrastructure, human capability and collaboration networks (nationally and internationally).

In considering priority national Capability areas relevant to the *An Environmentally Sustainable Australia* NRP, the Expert Working Group (EWG) paid particular attention to the need for:

- inter-disciplinary integration across natural and social sciences, economics and the humanities;
- a commitment to the research infrastructure underpinning sustained observations of critical components of the earth systems. Long time series of observations and improved spatial resolution are essential to improved understanding, prediction and planned adaptation to the impacts of climate variability and change and the direct impacts of society on the terrestrial, aquatic and marine environments;
- an environmental data capability designed to optimise discoverability, accessibility, interoperability and provision of model-ready data streams;
- linkages between the observing and analysis systems across biophysical, social and economic domains so that industries, the public and public policy makers can draw on the products of excellent collaborative science;
- the capacity to carry out process studies and experiments in areas of national priority; and
- systems level research into both our natural and human environments as well as our energy systems.

Emerging trends in research, consideration of Capability areas identified in the previous Roadmaps and underpinning requirements needed to support excellent research across relevant disciplines are discussed in this chapter.

Recently released national frameworks and plans for climate[12], marine[13], earth system science[14], cities[15], geoscience[16] and environmental information[17] provided useful guidance to the EWG on priorities in these domains. However, in other areas, broader research community input is needed to refine gap analyses and develop recommendations on priority investments.

Section A: Future research directions

In identifying key research areas as ongoing or new priorities, the EWG considered the fields in which Australia already has international standing and took into account community agreement around priority research directions. The key areas for future research are as follows:

- the global ocean and the oceanic regions surrounding Australia, as critical to detecting and attributing climate change and improving projections of the changes and their impacts;
- the role of the Antarctic cryosphere in the earth system and the changes resulting from global warming;
- ecosystem research into Australia's coastal zone, to inform sustainable development and improved understanding of the complex set of ecosystem – urban – industrial interactions;
- water resources (including groundwater) and management of these resources;
- our understanding of the terrestrial environment and biogeochemical cycles (e.g. water, carbon, nutrients) with a focus on Australian soils given their relevance to sustainable agriculture, carbon sequestration, forest production and water resource management;
- knowledge of Australia's biodiversity, including the identity and names of organisms, their genetic diversity, the relationships between organisms, and their functional role in ecosystems;
- geosciences, as they provide insight into areas such as understanding past climate patterns, possible ways to reduce adverse impacts of climate change, natural hazards and supporting the sustainable use of minerals, energy and groundwater resources;
- maintaining and building Australia's capability in palaeoclimate research as an important contribution to global climate science, recognising that the Australian Antarctic Territory is likely to contain the world's oldest and deepest ice;

[12] http://www.climatechange.gov.au/government/initiatives/~/media/publications/science/national-framework-cc-science.ashx
[13] http://www.opsag.org/pdf/opsag-marine-nation-01.pdf
[14] http://www.science.org.au/natcoms/nc-ess/documents/ess-report2010.pdf
[15] http://www.infrastructure.gov.au/infrastructure/mcu/urbanpolicy/index.aspx
[16] http://www.science.org.au/events/thinktank/thinktank2010/documents/thinktankproceedings.pdf
[17] http://www.environment.gov.au/npei/index.html

- research into the earth’s atmosphere, including the development of a greater understanding of the role of aerosols and clouds, particularly to support research into climate change and its regional impacts;
- understanding the physical and social aspects of built environments to improve the sustainability of cities and urban areas; and
- the development of alternative energy sources and multi-disciplinary energy research at the system level as critical to developing a truly sustainable energy supply.

1.A.1 What are your views on the key future research directions identified and are there other key areas that have not been included?

Section B: Research infrastructure Capability areas

Long-term and standardised observations of our environment are perhaps the most important contribution research infrastructure can make to support our understanding of how our environment is changing. This was a priority in the 2006 and 2008 Roadmaps and remains the top priority.

The Capability areas identified in the 2008 Roadmap are still the most appropriate. However, there should be greater emphasis on integration across the various domains (marine, aquatic, terrestrial, geological and urban) – particularly through adoption of a common approach to data discoverability, accessibility and interoperability. Integrated data sets support enhanced systems research, and should lead to better informed policy, decision making and management. These integrated data sets are a key requirement to support research to improve our ability to anticipate, innovate and adapt to a raft of game-changing pressures including the impacts of climate change and significant population/urban growth.

As a number of facilities in the relevant Capability areas have begun to collect and provide data, it has become clear that observational Capability areas would benefit significantly from closer working relationships between established observation-data management communities and the modelling communities that use their data to deliver enhanced systems understanding. This applies in the national sphere and increasingly now in the international context, as exemplified in the area of ocean observations, characterisation and related modelling. Similarly, where social and economic drivers are key elements of the system, more attention is required on the collection of and/or access to key social and economic data that are sensitive to change in environmental condition or function.

There is a need for continuing development of remote sensing capabilities, as they are a key platform for the provision of observational data of environmental variables across the key areas for future research identified by the EWG. It must also be recognised that data should be gathered and stored at the finest scale possible to allow maximum flexibility of later use.

The current Built Environments Capability area should have increased emphasis on the interface between the built and natural systems. To support a systems approach to studies into environmental sustainability of Australia's urban areas and assist in building environmental change into modelling and planning activities, a close linkage between urban and environmental data systems (and modelling frameworks) will be essential.

Australia's taxonomic capacity continues to decline which is of particular concern in light of Australia's unique terrestrial and marine biodiversity and related endemism. The infrastructure to support the suite of 'omics capabilities into understanding and tracking of biodiversity (including the necessary reference collections and next generation hardware) needs investigation. This will enhance Australia's capability to explore the emerging area of soil and ecosystem metagenomics as a logical adjunct to the establishment and expansion of terrestrial and marine ecosystem observations.

The current Capability area in the 2008 Roadmap focused primarily on energy sources (A Sustainable Energy Future) should be expanded to cover research infrastructure to support energy systems research, including smart grid and system optimisation technologies. Multi-disciplinary energy research at system-level is a complex new area of paramount importance in tackling climate change and assisting Australia to realise its aspirations towards environmental sustainability.

1.B.1	*What are your views on the research infrastructure Capability areas identified, including their relative priority and their ability to support the current and future research needs?*

Section C: Current investments

A brief description of the existing funded facilities is provided at **Attachment C**.

Significant NCRIS and Education Investment Fund (EIF) investment into Environmentally Sustainable Australia research infrastructure has been very successful and quite unique in supporting critical research infrastructure investment across a broad range of capabilities, especially in the long term observation of Australia's oceans, terrestrial environment and the solid earth.

The Integrated Marine Observing System (IMOS), Terrestrial Ecosystem Research Network (TERN), Atlas of Living Australia (ALA), Groundwater and AuScope are all valuable facilities and have made significant initial steps. Ongoing and additional investment into these observing and data collection systems will be critical to building quality data time series. Building on the highly collegiate nature of these facilities, there is a need to better integrate and to expand their coverage into identified thematic and geographic gaps, emerging areas and multi-disciplinary concerns. Further investment to support data accessibility, modelling and visualisation is also required to make the time series data as useful and usable as possible.

The EWG has primarily focussed in the following paragraphs on the areas it believes are not covered by the current investments.

Investment in ocean observation should be extended to cover the deep ocean, the under sea-ice environment, the Antarctic cryosphere and the oceanic regions surrounding Australia (tropical Indian, South East Asian, Southern, South West Pacific). Research infrastructure in these areas will support a strong blue water and climate science program that addresses priorities identified in the National Framework for Climate Change Science.

A renewed focus on terrestrial biogeochemical process and their relationship to fluxes of carbon and water is also required. New investment in atmospheric composition at the regional level, particularly aerosols and clouds, is required if we are to adequately understand the regional impact of climate change.

Australian expertise in earth sciences is world class and investments to date through AuScope have further emphasised Australia's high international standing. The EWG considers that additional investment is required in geophysical instrumentation that significantly improves our ability to resolve the physical state of the accessible crust (0-10 km depth). This will assist research in understanding how the crust will respond to interventions such as geothermal energy production, carbon dioxide storage and isolation of dangerous wastes, as well as furthering our understanding of earthquake hazards. Access to new experimental infrastructure is also needed.

TERN, IMOS, ALA and AuScope currently provide infrastructure for coastal zone research (with the seaward extent to the edge of the continental shelf). However, in the EWG's view the combined investments are inadequate for the scale of the coastal zone research and management/policy challenges.

The coverage of terrestrial ecosystem observations needs to be expanded to give a greater range and density. Although Australian Government programs (e.g. Commonwealth Environmental Research Facility - now the National Environmental Research Program) support research into rivers and estuaries, a lack of investment into research infrastructure in these systems has hampered the collection of long-term environmental data. Therefore investment must be extended into research infrastructure to support observations of fresh water ecosystems, covering not only quantity and quality, but also function.

The EWG considers that moves by the ALA to increase linkages to the 'omics facilities should be supported, which will further develop this key area of understanding and tracking biodiversity. Use of new taxonomic and bioinformatic methods, and a suite of new 'omics approaches to spatially quantifying biodiversity, will be essential.

The general platform technologies provided through the Australian Plant Phenomics Facility must be maintained and expanded to cover not only crop development but other environmental fields including studies into biodiversity.

The current investment in Australian Urban Research Infrastructure Network (AURIN) is a good first step, and AURIN's design, around thematic lenses, lends itself to integration with other Capability areas. The initial suite of lenses could be built on to develop an interactive suite of national built environment data that can intersect with complementary environmental data sets. This systems approach should lead to a greater ability to assess environmental impacts from population expansion, and predict the effects of natural hazards on humans and infrastructure.

The investments under the Sustainable Energy Future Capability area (Biofuels and Fusion) have been limited and the EWG supports additional investment, not only in the area of energy sources, but also research infrastructure to support energy systems research. Investment in research infrastructure to support new system-level energy research will be critical to decarbonise our electricity grid and attract the much needed massive investments to urgently transform electricity grid infrastructure.

1.C.1	*What are your views on the existing funded facilities, including their ability to meet the current and future research needs?*

Section D: eResearch infrastructure needs

The EWG considers that data integration, transmission, storage and access to simulations and models are an urgent priority.

While the existing facilities are making great progress in managing the observational data streams, there is an urgent need to accelerate investment in the necessary storage and access infrastructure and to ensure that all the data is accessible, discoverable, interoperable and gathered and stored at the finest scale possible.

The Australian National Data Service (ANDS), Research Data Storage Infrastructure (RDSI) project and the National Research Network (NRN) projects are contributing to improving these aspects, but more work is required.

Many of the Capability areas identified are reliant on access to supercomputing capabilities to process the large volumes of data received through remote sensing and ’omics based approaches, to undertake complex modelling and projection of the climate system and the natural environment. The continued development of the National Computational Infrastructure (NCI) is therefore vitally important.

For example, without urgent investment in the NCI storage capability, the next Intergovernmental Panel on Climate Change (IPCC) Assessment will be complete before Australian scientists have access to this important international petabyte size data set that is critical to understanding Australia’s future climate.

As the sophistication and time-space resolution of earth system modelling is extended it is reasonable to assume that Exabyte capability will be necessary to support simulation experiments within the next five to ten years.

1.D.1	*What are your views on the eResearch infrastructure identified, including their relative priority and ability to support the current and future eResearch infrastructure needs?*

Section E: Cross-disciplinary needs

Australia relies on Earth observation datasets provided by other nations and this reliance is a significant and recognised risk for our environmental planning and management. Investment in infrastructure is required to ensure that Australia can receive new data streams that will become available as a result of the launch of new satellites. The focus should be on verification/calibration of satellite systems, development of improved products suitable for assimilation into models and building of expertise in the use of these data sets. The increase in spatial and spectral resolution will continue to pressure the computational and storage infrastructure.

Technologies for geoscientific exploration have many potential applications in the environmental sciences and development of interdisciplinary capability is warranted, particularly in relation to airborne geophysics, informatics and proximal sensing of cores and boreholes.

The linkages to social science and humanities need to be strengthened, to increase the understanding not only of human impacts, but also to create better models and predictive tools for the future which can map how the environmental space interacts with the human space including taking into account population, behavioural change and resource use.

The infrastructure provided under the Characterisation Capability area is an underpinning requirement across the environmental space. This is particularly relevant to the extraordinary new vistas being opened up in biogeochemistry, which are allowing us new understanding of the origin of life, through to much more efficient sustainable mineral processing. A dedicated earth science synchrotron beam-line would extend the observational spectrum to real-time experiments at the nano-scale, some at pressures and temperatures representative of the deep earth.

The facilities provided under BioPlatforms Australia are essential to environmental research and in particular, the EWG identified a need for additional investment to support the emerging areas such as soil metagenomics and ecosystem metagenomics.

The EWG believes there is a continuing need to support research infrastructure for new energy sources, which is covered within the Frontier Technologies chapter in the 2008 Roadmap.

1.E.1	*What are your views on the cross-disciplinary requirements identified, including their relative priority and ability to support the current and future research needs?*

Section F: Current developments

The EWG noted that there are multiple policy and management interests that intersect with environmental research and research infrastructure. A key issue is the need to provide better pathways from the science to support good policy and efficient decision making and effective management.

Initiatives such as Australian Government's National Plan for Environment Information[18] provide a mechanism through which the full potential of research infrastructure could be harvested for multiple end users and applications. The push towards a more coordinated approach to environmental data in the government space may prove to be a driver for continued investment into environmental data research infrastructure.

The National Framework for Climate Change Science[19] is another important driver for research infrastructure investment that will support the national climate change science priorities identified in the Framework.

International developments, particularly relating to climate change, may impact on future research infrastructure investments. Australia should ensure it enhances its integration with international programs and alliances in regional/global environmental research through research infrastructure to support observations and modelling in areas which harmonise most closely with our capabilities.

Australia has a strong reputation for international leadership and collaboration in many areas of research covered by this roadmap. The benefits of our international collaborations include access to facilities not available in Australia, and greater leverage and return on science spending. Continued ability to access and expand these international collaborations is an important element of Australia's research capability.

1.F.1	*Are there other programs/issues/developments not listed that you consider could be a driver for future research infrastructure investments or may impact on such investments?*

[18] http://www.environment.gov.au/npei/index.html
[19] http://www.climatechange.gov.au/government/initiatives/national-framework-science.aspx

Promoting and Maintaining Good Health Expert Working Group

The *Promoting and Maintaining Good Health* National Research Priority (NRP) is aimed at promoting good health and well being for all Australians. This NRP has four priority goals: a Healthy start to life; Ageing well, ageing productively; Preventive healthcare; and Strengthening Australia's social and economic fabric.

The Expert Working Group (EWG) has identified priority national research infrastructure areas (Capability areas) of particular relevance to the *Promoting and Maintaining Good Health* NRP.

Emerging trends in research, consideration of Capability areas identified in the previous Roadmaps and underpinning requirements needed to support excellent research across disciplines are discussed in this chapter.

Australia has a strong and proud history of research across a broad range of fields that is aimed at promoting and maintaining good health.

As a nation, we have enjoyed multiple medical and health research highlights and our research has led to the award of several Nobel prizes. Over the past few decades, we have made fundamental discoveries across a range of fields, including neurology, infection and immunology, genetics, cancer, gastroenterology and cardiovascular medicine. Likewise, we have led the world in the development of a number of groundbreaking medical innovations, including devices for cardiology and respiratory medicine, and the cochlear implant.

In terms of public health, Australia has been at the forefront in a diverse range of health promotion initiatives including tobacco control, road accident prevention, educative response to HIV, prevention of SIDS and initiatives to increase folate intake before and during pregnancy. We have also undertaken a significant number of large-scale population-based cohort studies that have yielded insights into causal pathways of health and disease and life course trajectories of health and health-service use.

Australian researchers have demonstrated significant success in pioneering methods for drawing on research evidence to influence health policy-making, including using comparative effectiveness research to inform drug-funding policy. We have also proven to be an excellent host of many large-scale clinical trials; particularly due to the advantages of our well-curated clinical databases, our strong ethics/approval processes, high quality clinical researchers, cooperative public health systems, and an educated population to result in excellent compliance and high standards.

Australia boasts many exemplary groups of biomedical, clinical, population and public health researchers. These are mostly supported by excellent local infrastructure and a number of large population-health cohorts. However, to expand our national capacity for research excellence in the medical and public health arena, there is now a pressing need to focus on integration, particularly across existing centres and disciplines. Appropriate provision of the infrastructure to enable effective integration will provide for significant gains in the health of present and future generations – both nationally and globally. In particular, the tools for individualised provision of medicine and healthcare are now available, and will become more affordable over the coming decade; properly implemented, these will provide long-term savings to the national health sector. Provision of appropriate infrastructure is essential for research to be undertaken whereby these tools move from the domain of biomedicine and genetics to become standard fare for our clinicians and public health professionals.

Section A: Future research directions

Australia, like other developed nations, is challenged to find ways to best target health and aged care services in the context of an ageing population and finite resources.

Recent analyses, including the Excellence in Research for Australia (ERA) exercise, have confirmed that Australia has many world leading research groups across the disciplines of biomedicine, clinical medicine and public health. We will derive maximum benefit from the hosting of these groups through a wider provision of access to their facilities and databases for researchers from across the sector. Distributed infrastructure may be appropriate in some cases, however there will be other times where we can contemplate only a single national facility.

Internationally, the cutting edge in clinical research is being enabled through dedicated research facilities that can simulate clinical settings (e.g. the USA's National Institutes of Health Clinical Centres Research Program MO1[20]). Ideally located at a teaching hospital with an associated university or Medical Research Institute (MRI), such research-only centres would enable normal and abnormal physiological studies and investigator-driven clinical studies utilising a full range of diagnostic tools. Whilst ongoing funding for such centres is likely to be at 'landmark' scale, and therefore outside the scope of present consideration, there would be value in this model and the associated infrastructure requirements being considered. In some cases the installation of next generation infrastructure may be justified (e.g. particle research and therapy capabilities such as Hadron Collider – generated light and heavy ions).

Discovery phase medical research moves at a rapid pace, and over the past few years we have seen significant developments in equipment that allows for high-throughput analysis and improved resolution. The costs of such equipment will rarely be justified for use by a single institution and future purchases will need to be accompanied by innovative access and governance arrangements.

2.A.1	*What are your views on the key future research directions identified and are there other key areas that have not been included?*

[20] Division for Clinical Research Resources: Guidelines for General Clinical Research Centers Program (M01) National Center for Research Resources, National Institutes of Health, Department of Health and Human Services, October 2005.

Section B: Research infrastructure Capability areas

There is a well-recognised need to enable the introduction of up-to-date biological, physiological, pathological and imaging analyses into population-health and disease-specific cohort studies.

Enabling this need will require a continuing investment in:

- Bioinformatics;
- Genomic, metabolomics and proteomic analyses;
- Biomedical imaging (PET/CT, MRI/SPECT, SPECT/CT, retinal, etc); and
- Microscopy (Optical, Multiphoton and Electron microscopy).

As well as additional and effectively co-ordinated investment in:

- Cardiac and respiratory, and possibly other, functional analyses;
- Biobanking;
- Biostatistics; and
- Pathology.

Whilst the infrastructure requirements for such integration may involve new analysis equipment, there is also a valuable opportunity to work with existing centres and facilities. On this basis, appropriate ICT infrastructure needs will have to be carefully considered and balanced against requests for new equipment.

Many of the existing technology platforms that underpin Australia's biomedical research efforts were established and funded via national schemes. This has included some commencing operations under the Major National Research Facilities program (e.g. genomics and proteomics), with subsequent funding via NCRIS allowing for both continued and expanded operation as well as the introduction of new capabilities. Furthermore, very recent investment through the EIF has allowed the acquisition of additional infrastructure into some of these platforms.

Strong and effective governance around these capabilities is critical and is expected that better promotion of these platforms would allow better uptake across the national research sector. Although many large institutions often have similar capabilities, there is a clear need to have high quality platforms with state-of-the-art equipment that are freely available to researchers nationally without any real or perceived barriers to access.

Further funding for existing capabilities will have to be carefully considered and balanced against new investments. We are entering a stage in the provision of health services where it is hoped that clinical decisions and outcomes will be informed by the outcomes of the revolution in biomedical science and advances in understanding the effective prevention, early intervention and disease management strategies that has occurred over the past decade. The enabling infrastructure for this translation may be very different to those at existing facilities.

2.B.1	*What are your views on the research infrastructure Capability areas identified, including their relative priority and their ability to support the current and future research needs?*

Section C: Current investments

A brief description of the existing funded facilities is provided at **Attachment C**.

In the health and medical research fields, current nationally funded capabilities include: population health data linkage, proteomics, metabolomics, genomics, bioinformatics, phenomics, biomedical imaging as well as microscopy.

These platforms operate as a national network and variously provide open access to meritorious researchers or access to member institutions. They are generally well equipped and have considerable operating expertise. These platforms, some still in their relative infancy, certainly appear to be serving their local communities very well, however, a number are yet to engage the broader research community and thus have some way to go to achieve true national network status.

Current investments in the Population Health Research Network through NCRIS and Super Science are building a national infrastructure for population health and health services research using linked administrative data. The scope and population coverage of this infrastructure supports research to explore health differentials, geographic and spatial aspects of health, and the effectiveness of health and aged care services. There is potential to expand this infrastructure to support ongoing linkages with clinical trials, registries and the addition of biological data. Such development would dramatically expand the community of researchers using the infrastructure, as well as the scope and impact of the resulting research.

Some of this infrastructure will be addressed through the implementation of the Translating Health Discovery (THD) project (below) and the recommendations of the recent Clinical Trials Action Group (CTAG) report[21] to expand and develop support for clinical trials registries through the National Health and Medical Research Council (NHMRC).

The THD project is a two part investment forming an integral part of a broad vision aimed at achieving higher rates of translation of Australia's therapeutic discoveries into clinical applications. Translational health research can be loosely defined as 'the process of applying ideas, insights and discoveries generated through basic scientific discovery to the treatment or prevention of human disease. The THD project will address the research stage, manufacture of products for trials (e.g. microbial, human and animal cell products, development of pharmaceutical products and the conduct of clinical trials).

2.C.1	*What are your views on the existing funded facilities, including their ability to meet the current and future research needs?*

[21] http://www.innovation.gov.au/Industry/PharmaceuticalsandHealthTechnologies/ClinicalTrialsActionGroup/Documents/CTAG_Report.pdf

Section D: eResearch infrastructure needs

As the demand for health and medical researchers to generate and interpret vast amounts of information increases, provision of a high quality biostatistics and bioinformatics infrastructure will be essential. Increased investment in a national capability that can meet this need will position our investigators on the cutting edge of data analysis, and integration and collaboration through eResearch infrastructure investments will strengthen outputs and facilitate optimal translation of new knowledge across the sector.

Embedding bridging technicians in laboratories will provide the key to engaging with eResearch infrastructure. Likewise, as we build capability in eResearch there is a need to consider bioinformaticians, biostatisticians and computational modellers as part of the eResearch infrastructure. It also important for national data-sharing infrastructure to facilitate improved collaboration around the data generated across the research networks. To enable this, research communities will need to work proactively with national data storage, national data management and data discovery infrastructure initiatives. It is in this context that eResearch infrastructure be especially shaped to be the most meaningful to the medical and public health research community, and this will require the community to drive it internally. The core infrastructure alone will not necessarily meet those needs.

Computational imaging and visualisation are key emerging areas: this new technology brings a data deluge and resultant challenges around how best to manage the increasing volumes of data to extract meaningful information. Many transformational data visualisation techniques in play today are only very recent and the increased data volume generated presents particular challenges in terms of interpreting data on a larger scale.

eResearch infrastructure needs to evolve to incorporate secure and innovative solutions to the ethical and privacy challenges associated with the use of personal health information for research, including emerging resources of electronic health records and biodata. Australia is uniquely positioned for research leadership in this area due to its rich population-based data collections and the strength of existing research capabilities.

Finally, it is hoped that investment in the European Molecular Biology Laboratory (EMBL) European Bioinfomatics Institute mirror will provide access to significantly enhanced bioinformatics tools, and new collaborative potential with the EMBL nodes in Europe.

2.D.1	*What are your views on the eResearch infrastructure identified, including their relative priority and ability to support the current and future eResearch infrastructure needs?*

Section E: Cross-disciplinary needs

Since commencing operation in 2007, the Australian Synchrotron has become one of the most significant pieces of science infrastructure in the southern hemisphere.

The Synchrotron is internationally regarded as a world-class facility with three of its current nine beamlines considered the world's best.

Synchrotron science serves many different academic research disciplines and research carried out and/or planned for the Synchrotron addresses a broad cross-section of the national research priorities, including *Promoting and Maintaining Good Health*. In terms of outcomes, recent research conducted at the Synchrotron has provided unique insights into nanomaterial assembly, helped develop improved alumina extraction processes, led to advanced materials testing required for defence, new sensor technologies, new methods in the forensic sciences and aided in the development of anti-toxins to combat biological weapons.

With regard to the *Promoting and Maintaining Good Health* national priority, research at the Synchrotron has provided unique insights into cell biology and protein structures and is vital to the search for new drugs and anti-toxins. With the commissioning of the new Imaging and Therapeutic Beamline, the door has been opened to new approaches to diagnostic imaging and novel therapeutic strategies to treating life-threatening diseases such as cancer.

The demands for beamline time are such that only the most meritorious research projects (as judged by rigorous peer review) are allowed beam time; even then there are considerable waiting times on many of the beamlines. In light of this, continued investment in the Synchrotron and funding for new beamlines is essential if the Synchrotron is to continue to provide both a cutting-edge capability to the research community and to maintain its global leadership position.

Optimal provision and access to the suite of 'omics infrastructure is an essential capability, as it will be utilised extensively across a range of disciplines, given the shared technologies and applications. Similarly, development of a strong biostatistical and bioinformatics capability with open access will service many disciplines and develop into a key national resource.

The National Imaging Facility offers a broad spectrum of researchers access to molecular-imaging instrumentation, advice and assistance for a range of high field MRI and PET/CT scanners and other live animal imaging equipment including bioluminescence, microCT, ultrasound and intravital microscopy. The facilitation of access to PET/CT imaging and platform technologies (cyclotrons and radiochemistry) will provide cutting edge radiotracers for pre-clinical development and basic pathophysiological understanding.

In general there is a growing and unmet demand for many analysis platforms ('omics, imaging etc.) presently available for animal-based and cellular-based research to become available and accessible for clinical research.

2.E.1 What are your views on the cross-disciplinary requirements identified, including their relative priority and ability to support the current and future research needs?

Section F: Current developments

In support of the *Promoting and Maintaining Good Health* priority, the NHMRC, along with State of Departments of Health and partner universities have established a number of centres under the Centres of Excellence and Enabling Grants Schemes. In the near future it is expected that further recognition and investment will be made through the National Health Research Enabling Capabilities (NHREC) and the Advanced Health Research Centres (AHRC) schemes. Future investments in major infrastructure are likely to be most effective if they are linked to the critical mass of researchers present in such centres or in equivalent organisations.

Nationally coordinated tissue storage and biobanks would provide a globally unique infrastructure facilitating translational research. This would ensure open access, transparent governance and maximise international collaboration/utilisation. In some areas, investment would synergise and build on capability already present via the NHMRC enabling grant system. This system has not always provided investigators with an ideal model of access and provision of tissue necessary for high quality studies.

Australia is in the midst of a revolutionary hard infrastructure program, specifically targeted at translational health research. Major projects include the Victorian Comprehensive Cancer Care Centre (Victoria), Translational Research Institute (Queensland), South Australian Health and Medical Research Institute (South Australia), Fiona Stanley Hospital (Western Australia), Western Australia Institute for Medical Research and QE2 campus redevelopment (Western Australia) and the Centre for Obesity, Diabetes and Cardiovascular Research (New South Wales).

The current investment into the THD project ($35 million from Super Science) is an integral step towards achieving higher rates of translation of Australia's therapeutic discoveries into clinical application. Translational health research is loosely defined as 'the process of applying ideas, insights and discoveries generated through basic scientific discovery to the treatment or prevention of human disease'.

2.F.1	*Are there other programs/issues/developments not listed that you consider could be a driver for future research infrastructure investments or may impact on such investments?*

Frontier Technologies Expert Working Group

The *Frontier Technologies for Building and Transforming Australian Industries* National Research Priority (NRP) is aimed at stimulating the growth of world-class Australian industries and supporting Australian research using innovative technologies developed from cutting-edge research.

This NRP has five priority goals: Breakthrough Science (better understanding of fundamental processes); Frontier Technologies (examples include nanotechnology, biotechnology, photonics, genomics/phenomics, complex systems and ICT); Advanced Materials (includes ceramics, biomaterials, organics, polymers, smart material and fabrics, composites and light metals); Smart Information Use (improved data management); and Promoting an Innovation Culture and Economy.

We are living in an era of biology-chemistry-physics-engineering convergence and many exciting future advances will occur at the interfaces between these disciplines. Therefore future research infrastructure investments should consider significant cross-disciplinary capability building. In addition, future investments should consider developing capabilities and access models that will directly contribute to building and transforming Australian industry.

It is clear that for many areas of research in frontier technologies, international participation and/or international teams have become the essential basis on which the research effort is conducted. In astronomy, this is now well entrenched and international competitiveness depends on international participation. This trend is likely to continue to build in other areas as well.

Emerging trends in research, consideration of Capability areas identified in the previous Roadmaps and underpinning requirements needed to support excellent research across relevant disciplines are discussed in this chapter.

Section A: Future research directions

This Expert Working Group (EWG) has particularly focused on the four Frontier Technology areas of advanced materials, astronomy, computational and simulation science, and sensors and measurement systems. (Note that ‘sensors and measurement systems’ incorporates developing new approaches to measurement, whether that be of biological properties via advances in the ’omics suite of technologies, photonics or other technologies capable of creating new measurement tools.)

A global trend, common to all future technology areas, is the move to accelerate the discovery process. A stronger emphasis on fast-tracking discoveries, as well as the translation of frontier technologies, is necessary for Australia to remain internationally competitive in science and engineering. It is evident that in Australia the uptake of combinatorial and high-throughput experimental methodologies has been slow outside of the life sciences. This situation needs to change.

High-throughput methods in research are a departure from the traditional practice of investigating one aspect at a time in a serial framework. The approach involves developing integrated, often highly automated, capabilities for testing a range of characteristics in parallel. The rapid accumulation of large volumes of data, coupled with protocols to transform information into knowledge, can help guide and optimise discovery. Work flow is critical in fast-tracking the discovery process, with efficiency governed by strategies developed to accelerate processes within steps and to avoid bottle necks between steps. It is also important that we develop mechanisms for trialling and embedding emerging measurement technologies within established high throughput protocols.

It is suggested that the future research infrastructure roadmap should incorporate a holistic approach in mapping the elements of the ‘discovery chain’ specifying the key elements that need to be supported or developed, and identifying how these elements may be integrated. This might involve, for example, providing support for bringing together complementary frontier technologies to create a multi-function device, integrating emerging frontier technologies upon existing commercial systems, or combining frontier technologies and other capabilities to address a national research challenge.

Advanced materials are materials which, as a result of innovative design, synthesis, fabrication or processing techniques, acquire novel structures or superior properties. There is continuing high demand for materials with step change improvements in performance to address major unmet needs in areas such as health, transport, energy, natural and built environment, communication and defence. Next generation materials will include multifunctional materials (e.g. biomedical materials that are combined targeted drug delivery and medical imaging agents or combined stem cells and functionalised scaffolds), adaptive materials (such as possessing the ability to self-heal when damaged) and smart materials (such as materials with the ability to monitor corrosion or strain). New materials and their engineering into novel applications to address sustainable energy will additionally be an important focus. In addition to the design and development of these advanced materials, there is also a need to develop high performance processing routes with low environmental impact for existing materials.

The future of **Astronomy** research will continue to be focussed on understanding the fundamental physics that drives the Universe. Such knowledge will be gained by answering key questions on the origins and evolution of stars and galaxies; probing the physics of extreme environments; gaining deep understanding of the fundamental forces and the forms of matter and energy that make up the universe; and studying the building blocks of life. In order to achieve this, ever higher resolutions, fainter signals and more distant objects must be studied across increasingly large parts of the spectrum.

Computation is well established as a third route to scientific discovery. In science it sits alongside experimentation and theory as mainstream research practice, in the physical sciences, and is becoming increasingly important in biological, economic and social sciences.

The practical applications of Computational Engineering to the design and optimisation of new products and processes is now wide spread across technical and consumer products and major industrial and societal infrastructure. This highlights that simulation and modelling are also central to modern engineering practice.

More recently, the emerging data-centric model in research, driven by the so-called ‘data deluge’, which originated in the physical sciences (e.g. physics, astronomy) and is rapidly expanding in genomics and bioinformatics, medicine, microbial genomics, along with ecology and environmental sciences; and now spreading to less traditional areas such as social sciences, arts, and economics. This constitutes a possible fourth route: data-intensive scientific discovery.

The availability and performance of **Sensors and measurement systems** for measuring biological, chemical, physical or other parameters limits the scientific questions that can be asked in many areas of research. This is particularly apparent in the biological sciences, which traditionally rely on commercially available systems (most notably the ’omics platforms, but also including assays, microarrays, and other systems). In the physical sciences, most particularly the experimental disciplines, much research is focussed on expanding the range of measurable quantities.

Increasingly, there are strong opportunities to accelerate research and drive commercial technology transfer via facilitating the rapid adoption and adaptation of emerging frontier technologies between disciplines and research communities. Clear opportunities exist in integrating emerging frontier technologies with existing commercial systems.

3.A.1 What are your views on the key future research directions identified and are there other key areas that have not been included?

Section B: Research infrastructure Capability areas

The existing suite of national capabilities services a wide range of users and provides support services. The Australian National Fabrication Facility (ANFF) and the Characterisation capabilities all offer services to the research user to assist with access to and use of infrastructure.

The logical evolution of the services offered by existing and new capabilities is to extend these services towards a **‘Concept and Development Facility’** to assist researchers and industry users through the ‘discovery chain’. For example, the Facility could offer proof of concept, prototyping, experimental and computational design services. For experimentation, this would include the design of ‘discovery chain’ workflows and prescribing access to necessary capabilities. For industry users, this would fast track development of proof of concept and prototypes, analyse proposed product and process innovations to reduce risk, and contribute to innovation and the transformation of industry practice. This Facility could assist with access to overseas infrastructure, building on existing overseas programs offered by most of the existing capabilities. Such a Facility would support the convergence of physics, biology, chemistry, engineering, and computational sciences.

Implicit in this is the exploration of developing the research infrastructure within this Concept and Development Facility for **high throughput techniques**. High-throughput and combinatorial materials science is a methodology aiming to dramatically increase the productivity of new advanced materials ‘discovery chain’ steps. It enables efficient testing of structure-property and structure-processing hypotheses as well as markedly accelerating the development of novel advanced materials. The high-throughput ‘discovery chain’ work flow frequently involves design, synthesis, processing, structure and property characterisation, fabrication, performance evaluation and optimisation. The ultimate aim is to innovate from first principles based on a fundamental understanding of structure-processing-property relationships.

It will be necessary to further develop computational and simulation science on multiple length scales from quantum/atom through molecular, nano, colloidal, micro, meso and macro in order to fast-track the identification of prospective structure-property-performance correlations for direct experimental exploration.

Realising this vision will require an integrated approach to infrastructure. Although previous investments in research infrastructure through NCRIS/EIF/Super Science have supported a number of activities in the areas of Fabrication and Characterisation which have served to establish a number of world-class research capabilities, moving to a ‘discovery chain’ model and a Concept and Development Facility is desirable to ensure maximum exploitation of these facilities and maximal advantage by cross-linking of the capabilities of these distributed facilities as required.

Characterisation: There is a continuing need for enhanced investment in this area to provide state-of-the-art characterisation capabilities. Future trends will likely include (i) the addition of the temporal dimension so that dynamic processes can be probed in real time, (ii) the combination of a number of measurement modalities so that varied materials properties (magnetic, electrical, optical etc.) can be simultaneously measured at high resolution and (iii) high throughput work flow integration in the ‘discovery chain’. A new generation of ‘nanoscopies’ promises optical resolution at the 10nm scale. It will be important for researchers to have access to state-of-the-art infrastructure as well as infrastructure to support the development of new characterisation modalities.

Fabrication: The capabilities established as part of the ANFF provide wide-ranging research infrastructure for the fabrication of micro/nano structures and devices that encompass a diverse range of areas including biology, electronics, photonics, advanced materials, microfluidics and microelectromechanical systems (MEMS), which have a major impact in the other National Research Priority areas. This area requires continued investment in order to remain internationally competitive, and future trends are likely to include the development of hybrid materials platforms and devices that incorporate photonic and biological chemical functionalities.

Astronomy: Future astronomy research infrastructure will become increasingly expensive and larger scale in terms of size and complexity. As such, it will become increasingly international, requiring multi-national partnerships in order to be able to afford and operate it. Key examples are the Square Kilometre Array (SKA) and Giant Magellan Telescope (GMT), both of which will be billion-dollar projects that will involve global participation (spanning Australasia, Asia, North America and Europe).

Australia needs to have the appropriate research infrastructure funding mechanisms and governance arrangements in place if it is to be an effective player in such global projects. Increasingly, accessing and participating in international membership of facilities will provide the most effective way of managing future research infrastructure investments in astronomy by delivering an evolving portfolio of astronomy facilities and access arrangements.

A portfolio of facilities is needed to do world-class science, including continued and future access to facilities such as 4-metre and 8-metre class optical telescopes, survey telescopes, extremely large optical telescopes, national radio observatories and a range of telescopes operating across the spectrum. The development of state-of-the art instrumentation for existing facilities will also provide the capability required to address some aspects of the big questions.

Computational and Simulation Science: Data-intensive scientific discovery is a future direction for research globally, due in large part to the ‘data deluge’ across numerous disciplines. As with ICT generally, the pace of change is relentless. Nevertheless research productivity gains have been limited often due to: relative novelty of technology and practices, skills and ease-of-use. This can illuminate the path forward: sustained infrastructure investment, accompanied by training and education programs in computational techniques and in the design and use of robust models. Most critical is a clear focus on research user needs and usability of the technologies.

Realising the benefits of the ICT advances will entail a phase change in algorithms and simulations practices, a coming revolution that should inform initiatives in Australia. While such systems would only rarely be available to Australian researchers in the near term, their impacts would be felt through discoveries enabled and competitive pressures.

Sensors and Measurement Systems: This area needs to establish capabilities that bring together emerging materials systems and fabrication technologies to create new forms of sensing devices capable of measuring the chemical, biological, or physical characteristics of systems of a diverse range of scales ranging from single molecules to entire ecosystems. Such devices will increasingly need to be capable of multiplexed sensing, of being integrated with other sensing modalities and high throughput techniques.

This will impact on a broad range of areas of research and industry spanning from the environment and agriculture, medical diagnostics and fundamental discovery in the biological sciences, and in safeguarding Australia. Much of this activity can be undertaken by building on the scope of the current area of ‘fabrication’. Sensors and Measurement Systems will have strong synergies with the areas of advanced materials, characterisation, and fabrication, and needs to build and expand on existing capabilities.

Engineering Systems Research: Opportunities for the development of advanced materials, power electronic device technologies, and innovative engineering of large-scale renewable energy plants, are particularly relevant to future low-carbon transport and energy systems that will rely on electric vehicles and smart grid renewable energy technologies, respectively. Such developments include small-scale but widespread applications, for example high-power/high-temperature power electronic devices and modules based on emerging wide-bandgap semiconductor technologies and associated packaging, to large-scale systems, for example advanced forming techniques for turbine components. Infrastructure investments to support engineering development of new materials will facilitate development and eventual commercial deployment. Examples could include research infrastructure to support scaled-testing of renewable energy devices and research facilities for large engineered structures.

3.B.1	*What are your views on the research infrastructure Capability areas identified, including their relative priority and their ability to support the current and future research needs*
3.B.2.	*Should there be a shift in the balance between funding new infrastructure and funding expertise to serve the needs of researchers?*

Section C: Current investments

A brief description of the existing funded facilities is provided at **Attachment C**.

The existing suite of NCRIS/EIF/Super Science facilities service a wide range of users. However, there are gaps in meeting existing and future needs.

The Introduction to this Discussion Paper stresses the need for access to expert and skilled technicians to operate the advanced platforms and to train users. But beyond the need for the support for individual platforms is the need for **integration** of capabilities, as described in Section B above.

In Section A, the importance of accelerated materials discovery and managing work flow in the ‘discovery chain’ was stressed. The tools and expertise for materials informatics are not presently available, and this is likely to be a rapidly developing area in the future, requiring not only large computer resources, but also high throughput synthesis, processing, testing and characterisation.

On the international front, the international synchrotron access program offers assistance to researchers to use overseas facilities, and the optical and radio astronomy researchers are supported to use Gemini and buy into the GMT.

However, as research in other areas becomes more international in focus and scale, there will be the need to broaden support for Australian participation in overseas initiatives and consortia. For example, consideration could be given to

Australia joining the European Eight Framework Program (FP8), thus enabling Australian researchers to gain full access to EU projects and partners.

3.C.1 What are your views on the existing funded facilities, including their ability to meet the current and future research needs?

Section D: eResearch infrastructure needs

Frontier Technology research will continue to depend on eResearch infrastructure to support access to the Frontier Technology facilities and associated processing of the generated data.

Access to the Facilities

The Frontier Technology facilities will increase their capabilities to interactively process, analyse and display data in real-time. This will provide researchers with more capabilities to respond to situations during an experiment and make more effective use of the facility. Examples include the use of embedded systems (e.g. sensors) and image processing (e.g. 3-D and 4-D image reconstruction). The emergence of Graphic Processing Unit (GPU) technologies will be increasingly used in equipment, instruments and sensors.

The operation of facilities will become more automated allowing easier access for operational staff and researchers. This should reduce the need for specialist staff to operate the facilities and provide researchers with more direct interaction with the equipment. The automation will involve new instrumentation, display systems and monitoring tools, controlled through more powerful computer systems. It will also involve automated techniques to record metadata for subsequent analyses.

Remote access to facilities will increase in the future through tele-observation and tele-operation. Demand for this capacity is likely to arise from more opportunities for researchers to collaborate remotely through videoconferencing and more advanced versions of tele-presence. This will enable geographically distributed research groups to bring different kinds of expertise during an experiment.

The costs of developing and supporting Frontier Technology facilities, and specific requirements around the location of some facilities, will mean that not all leading-edge infrastructures can be installed in Australia and access to overseas facilities will be necessary. This is already happening in astronomy and fusion research. Access will depend on high-speed international networks with the capacity for high-volume data rates on demand. Planning for these networks need to be coordinated as part of the National Research Network Project.

Associated Data Processing

The amount of data and ancillary material generated by Frontier Technology facilities will continue to increase dramatically.

Computing Capability

Researchers will need access to more powerful computing systems to process and analyse this data. Some researchers (e.g. in astronomy, energy, particle physics) will follow the trend in computing power that will deliver exascale class systems around 2018. Other research areas may benefit from innovations in cloud computing and tools.

There will be an increasing need for interactive data processing allowing researchers to steer the analysis during the computation, rather than doing another job.

Data Management and Access

The high volumes of data will need to be managed and made available to the research teams and their community. Automated tools and techniques for managing the data will be necessary to reduce the dependence on specialists to curate and preserve data collections.

Computational Tools and Visualisation

There will be an increasing need for researchers to have a range of software tools for processing the data sets. These include data modelling and simulation, involving multi-scale, multi-modal models; data mining, pattern search and discovery, on large scale data sets; and interactive visualisation of complex data sets.

Some of the leading computational tools are being developed as open source software by multinational groups and Australia should participate in the groups that are relevant. An example is the International Exascale Software Project which is developing a roadmap for the next generation of software for key applications including astrophysics, climate and atmospheric science, biological sciences and energy research.

There will also be an increasing dependence on commercial software and systems (as indicated and enabled by the trend towards cloud computing). Software development will need to consider the overall costs to design and maintain software in the context of the costs and licensing mechanisms of commercial software. This is likely to result in larger communities developing and supporting software for the research community.

Virtual Laboratories

There will be an increasing need to integrate the data processing capabilities with the Frontier Technologies facilities. This will require the development of workflows that allow easier access to the facilities and eResearch infrastructure. The development is likely to require more collaboration between researchers leading to virtual laboratories and research communities.

The trend towards integration of Frontier Technology facilities and eResearch infrastructure will require closer engagement between the providers of these facilities. The current model of having several groups responsible for eResearch infrastructure makes this engagement difficult and models where the engagement is driven and directed by the researcher community should be developed.

3.D.1	*What are your views on the eResearch infrastructure identified, including their relative priority and ability to support the current and future eResearch infrastructure needs for Frontier Technologies?*

Section E: Cross-disciplinary needs

It is critical to provide research infrastructure that is capable of supporting cross-disciplinary needs. Internationally competitive research requires access to large state of the art infrastructure that serves a broad range of areas of research and also because there is an increasing need for infrastructure that supports research that sits at the boundaries of existing discipline areas.

Some of the existing funded capabilities clearly deliver infrastructure that is cross-disciplinary; good examples of this include the Australian Synchrotron and the National Imaging Facility.

There are other areas where there are clearly gaps or only embryonic capability at present, and examples include:

- Integration of the full 'discovery chain' of advanced materials development from materials design and properties modelling, through processing, characterisation and device fabrication;
- Interfaces between commercial/off-the-shelf biotechnologies and sensor and bionics development and engineering, including via the provision of infrastructure and laboratories for the co-location of researchers from these different disciplines to allow the testing and prototyping of new device concepts;
- Capabilities for designing approaches and solutions to problems that require access by researchers from other disciplines to frontier technologies;
- Capacity and support systems that facilitate use by frontier technologies researchers and industry of established service infrastructure and systems; and
- Facilities for visualisation of complex data sets and simulations across multiple scales (e.g. nano-scale up to full size structures) and domains (e.g. optical and mechanical).

In addition to the requirements for access to high quality large-scale cross-disciplinary infrastructure, and facilities for conducting high value cross-disciplinary research and integration, it is also important to have access to experts to assist and advise users on the use of cross-disciplinary facilities.

3.E.1	*What are your views on the cross-disciplinary requirements identified, including their relative priority and ability to support the current and future research needs?*
3.E.2	*Are there particular areas of research strength within Australia that could be harnessed to create powerful new research capacity and impact through the provision of new cross-disciplinary infrastructure and expertise?*
3.E.3	*What could be done to enhance the capacity of Australia's Frontier Technologies research to impact research, industry and policy in other priority areas (Health, Safeguarding Australia, etc.)?*

Section F: Current developments and other issues

As discussed earlier in this chapter, it is clear that for many areas of research in frontier technologies, international participation has become the essential basis on which the research effort is conducted.

A holistic rather than modular approach to capability building should be encouraged to cultivate and gain advantage from integration of the facilities. For example, clarification is needed to rationalise or relax the categorisations used to describe infrastructure that is supported under particular capability headings, for example, if a characterisation tool is absolutely essential in a particular fabrication facility, it should be possible to fund under the fabrication capability, and to treat it as part of the fabrication facility.

3.F.1	*Are there other programs/issues/developments not listed that you consider could be a driver for future infrastructure investments or may impact on such investments?*
3.F.2	*Do NCRIS/EIF/Super Science Frontier Technologies investments adequately balance the needs between science and engineering?*
3.F.3	*Is the current research infrastructure and proposed future emphasis adequately able to assist in building and transforming Australian industries?*

Safeguarding Australia Expert Working Group

The *Safeguarding Australia* National Research Priority (NRP) addresses threats to national security from invasive diseases and pests, terrorism and crime, while strengthening our understanding of Australia's place in the region and the world, securing our infrastructure, particularly with respect to our digital systems, and transformational defence technologies.

The National Security Science and Innovation Strategy (NSSIS) released in November 2009 provides a policy context for investment in research infrastructure supporting the Safeguarding Australia NRP. Importantly, the NSSIS focuses on science and innovation for non-defence national security, noting that the Defence White Paper gives strategic guidance to science and technology capabilities supporting the Transformational Defence Technologies NRP priority goal, primarily delivered through the Defence Science and Technology Organisation (DSTO).

In aligning this chapter with the Safeguarding Australia NRP and the scope of the NSSIS, the Expert Working Group (EWG) focused on research infrastructure supporting non-defence national security[22] noting, however, that there is potential for greater integration and access between defence and non-defence related research infrastructures providing appropriate security processes are in place across the system.

While no clear demarcation or defining principles were articulated, the EWG has consciously put research considerations at the fore, and any additional uses of infrastructure in relation to enhanced operational deployment were not an explicit consideration.

Previous Roadmaps have had a strong focus on biosecurity within Safeguarding Australia. In this chapter, the EWG has attempted to look much more broadly, encompassing the wider intent of the NRP, while still maintaining a keen focus on Australia's biosecurity system and its ability to support national and global food security, environmental/ecosystem health and mitigate infectious animal and human diseases.

It should also be noted that the EWG considered that there is potential for greater integration and access between defence and non-defence related research infrastructures providing appropriate security processes are in place across the system. While no clear demarcation or defining principles were articulated, the EWG has consciously put research considerations at the fore, and any additional uses of infrastructure in relation to enhanced operational deployment were not an explicit consideration.

In relation to emerging trends in research, consideration of Capability areas identified in the previous Roadmaps and underpinning requirements needed to support excellent research across disciplines are discussed in this chapter. The final section of this chapter discusses broad policy issues that are considered

[22] Defined broadly by the EWG as national security issues not involving the defence forces, classified intelligence agencies, or state on state warfare.

important to research infrastructure in this area, but are not directly related to the identification of future needs or capabilities.

Section A: Future research directions

The EWG considers the 21st century to be an era of threats arising from a changing climate, increasing levels of mobility, greater urbanisation, diverse demographics and population growth, leading to greater stress on ecological systems, changes in the threats posed by crime and terrorism, and requiring changes in urban design.

Given the broad nature of the Safeguarding Australia domain a number of future research themes were identified that will impact heavily on future research infrastructure requirements. These themes are:

- enhanced food security, including export continuity for Australian agricultural products;
- human health;
- environment/ecosystem health;
- countering crime and extremism; and
- physical and cyber infrastructure security.

Food security research is focused on developing cost effective methods of collecting and maintaining appropriate data to ensure the nation maintains its disease free status in many agricultural products, and effectively deals with any future outbreaks of disease. Additionally, agricultural productivity (disease free plants and animals) is a key research direction for food security research. Australia has limited capacity to increase its terrestrial food production; in an increasingly hungry world, the marine environment offers potential, but the biosecurity issues remain poorly understood.

Human health biosecurity research is primarily focused on animal-transferred (zoonotic) diseases. Emerging zoonoses continue to be a major threat to human health and animal management, with over 70 per cent of new human diseases being demonstrated to come from animals. Due to our geographic isolation and strict customs laws, Australia is in a unique position to build upon existing capacity and become a world leader in the field of biosecurity risk and containment research.

Environment/ecosystem health research focused on risk modelling related to predicted climate change scenarios will need to grow to inform both policy and environment and production management. The protection of Australia’s indigenous flora and fauna from infectious disease (whether domestic or introduced, endemic or emerging), overuse/degradation, or illegal trafficking is integral to the nations biosecurity. The migration of endemic, yet currently localised, diseases and pests to new areas as climate change and environmental degradation impacts are considered to be an emerging field of research concern.

The identification and prevention of the planning and execution of unlawful acts against Australian citizens is a feature of research into *countering crime and extremism*. Linking and integrating social datasets to conduct large-scale surveys using digital means is assisting socio-cultural research into methods to identify and prevent organised crime and terrorism-related radicalisation of the populace and social resilience to any such radicalisation globally. Decreasing prices for high-tech devices and ready access to information on the internet is also driving research into new methods of traditional and digital forensics and the utilisation of sophisticated techniques and best practice models for non-polemic extraction of evidence from an incident or scene.

Protecting Australian infrastructure from harm from natural disasters, deliberate acts of sabotage and accidental damage is the foundation for *infrastructure security* research. Knowledge pertaining to the resilience of physical infrastructure from such events would be facilitated through the sharing of engineering testing data and open access to research facilities. Recent natural disasters have heightened awareness of the necessity of this research.

Cyber-infrastructure security research is driven through threats that emerge both from theoretical and real-world examples. The recent real-world outbreak of the Stuxnet worm, infecting System Control And Data Acquisition (SCADA) technology of nuclear power stations and other industrial systems, has driven research into protecting systems that have traditionally been considered hardened and secure.

4.A.1	*What are your views on the key future research directions identified and are there other key areas that have not been included?*

Section B: Research infrastructure Capability areas

Much of the future research infrastructure relevant to Safeguarding Australia will be predicated on a number of key capabilities relevant to all research areas:

- access to disparate and dispersed datasets owned by multiple parties;
- access to deep and wide geospatial data from both domestic and foreign sources;
- the application of a strategic risk based approach and analysis; and
- advanced modelling and scenario development capabilities.

Seven broad research infrastructure capability groupings were identified to support the research directions identified in Section A. These capabilities are deliberately broad in scope, and do not in any way represent finalised thinking by the EWG.

Biosecurity infrastructure was identified in previous roadmapping exercises and remains a priority with evolving infrastructure requirements including: secure access to characterisation and systems biology facilities; links to geospatial, meteorological, forensic and specialised human health infrastructure as well as a need for Physical Containment Level Three (PC3) and PC4 facilities for a range of research such as aquazoology, companion animals and specialised flow cytometry containment tests. There is some discussion around the availability of containment facilities at all levels of security for dealing at the research level with large animals.

There is a need for *geospatial and linked mapping data* currently held across a wide range of domains and disciplines in both the national security and civilian space to be seamlessly and securely accessible. Such capability would link the databases of geospatial and mapping data held by the Bureau of Meteorology, Geoscience Australia, CSIRO, the Department of Defence, the Department of Agriculture, Forestry and Fisheries, and other large database holders in a secure and accessible manner.

Australia maintains world class *physical infrastructure resilience and response capability* including the Australian Maritime College's cavitation research laboratory, DSTO's explosive blast laboratories, CSIRO's fire testing facility and Victoria University's Large Scale Experimental Building Fire Facility, which currently exist in isolation from each other. A linking information technology fabric, allowing separate tests to be collected and built into advanced modelling and scenario creation technologies would support future infrastructure builds, better utilise current research infrastructure capabilities and encourage reuse of individual tests and models.

Additionally, the EWG believes gaps in this capability need to be identified, particularly in relation to testing facilities for risks arising from a changing climate, earthquake testing facilities etc. Longer term, the EWG sees this capability supporting planning and response scenarios, linking into the newly established National Crisis Coordination Centre and their state-based analogues.

Initially identified in 2006, *strategic risk analysis* is supported by the NSSIS and was further supported in the 2010 One Biosecurity – a working partnership (The Beale Review)[23] which emphasised the need for a risk assessed approach to national biosecurity. The complex and dynamic nature of the security environment spans a diverse spectrum of threats, including countering extremism, crime, bio-security and natural hazards, highlighting the need for coordinated infrastructure that would provide a platform for risk analysis across disparate research communities.

Existing contributions to *cyber-infrastructure resilience* need to be supplemented by a well-resourced, robust and distributed research infrastructure which can allow researchers to gain similar agility to attackers, thus allowing defenders to better anticipate and understand the nature of new threats. A facility providing for a combination of government, academic and private sector contributions to a national capability through information exchange, research collaborations and infrastructure sharing would create the foundations for building a considerably expanded pool of human and technical capability in this area.

Existing investments in the *digital forensics* are largely related to specific sectors of the criminal, defence and intelligence agencies. The capacity to share this data is limited by confidentiality and restricted information clauses, often due to

[23] http://daff.gov.au/__data/assets/pdf_file/0010/931609/report-single.pdf

operational concerns. A facility providing options for a combination of government, academic and private sector contributions to a national capability through information exchanges and research collaborations would create the foundations for building human and technical capability in this area.

A capability allowing researchers to better share sociological and population datasets would provide a robust platform for the development of better methods of identifying criminals, terrorists, and other forms of radicalisation in Australia, and social resilience to terror and crime events. Existing data is stored in a variety of forms at disparate loci across the nation and is inaccessible to national security researchers. It is acknowledged that a *national security sociological data network* capability would require legislative change to facilitate access to data and would encounter high levels of resistance from data holders, necessitating a strong governance and ethical structure.

4.B.1	*What are your views on the research infrastructure Capability areas identified, including their relative priority and their ability to support the current and future research needs?*

Section C: Current investments

NCRIS Investments

All current NCRIS investments in Safeguarding Australia have fallen into the biosecurity domain. NCRIS has endeavoured to provide for a better connected national biosecurity system, initially in respect to laboratories, through investments into the Australian Biosecurity Intelligence Network (ABIN) and Australian Animal Health Laboratory (AAHL) under the Networked Biosecurity Framework capability.

A brief description of the existing funded facilities is provided at **Attachment C**.

ABIN is beginning to address many of the issues of data sharing and real-time sample diagnosis across jurisdictions and agencies for biosecurity. Similarly, the steps to open up AAHL to access by other biosecurity researchers, through the AAHL Collaborative Biosecurity Research Facility, are beginning to provide training and access to PC4 and specialised PC3 biocontainment facilities, reducing any duplication in these facilities. The EWG noted the value of integrating the work currently being undertaken under the Atlas of Living Australia and the value of integrating this with the approach of ABIN and other data.

Non-NCRIS Investments

NCRIS and Super Science do not provide funding for non-biosecurity non-defence national security research infrastructure. The CSIRO, the Department of Agriculture, Fisheries and Forestry, state departments of primary industry and various health departments undertake significant investment in biosecurity research infrastructure, often employed as dual-use research and operation infrastructure.

Investment in non-biosecurity research infrastructure tends to reside in restricted or non-accessible areas such as the Department of Defence, Defence Signals Directorate, Police (Federal & State), Australian Security Intelligence Organisation, DSTO, universities and private laboratories or consultancy houses (KPMG, Deloitte, Ernest & Young), but is not coordinated or collaborated in any meaningful way across the domain areas, or between agencies or jurisdictions.

4.C.1	*What are your views on the existing funded facilities, including their ability to meet the current and future research needs?*

Section D: eResearch infrastructure needs

Safeguarding Australia, like all research today, is highly dependent on eResearch infrastructure to undertake its activities, particularly in the realms of data, integration and connectivity, and secure channels to facilitate research activities (including secure access to research infrastructure). Additionally, as capabilities move towards greater simulation and scenario testing, the requirement to access high performance computing resources will increase.

Data management requires increased access to disparate and diverse sets of data, often owned by other agencies or projects, and the ability to draw from large sets of data to combine such sets to create information and knowledge.

Data security includes data protection, database and systems security, data integrity and incorruptibility and tracing of data sources. Secure data stores will become increasingly important in the future, with legislative requirements that data be maintained on Australian servers in a secure manner meaning that more conventional solutions (such as the commercial cloud) cannot be utilised.

Integration and connectivity supporting the ability to integrate data and information from different sources, collaborate with dispersed personnel, and access geographically spread instrumentation in a secure manner are integral to the future of any research to be undertaken in the Safeguarding Australia sector.

Secure access channels focused on the ability to access and utilise data, resources and personnel in a secure manner. A long-term eResearch need will be for an Australian Access Federation (AAF) type service to exist that will facilitate security at the levels required by national security-related researchers. (Current work of the AAF is not at a high enough security level).

4.D.1	*What are your views on the eResearch infrastructure identified, including their relative priority and ability to support the current and future eResearch infrastructure needs?*

Section E: Cross-disciplinary needs

Non-defence national security draws across a wide and diverse spectrum of current research investments including: fabrication, imaging (Australian Nuclear

Science and Technology Organisation, Australian Synchrotron), data linkage activities (Population Health Research Network) and characterisation services (National Imaging Facility, Australian Microscopy and Microanalysis Research Facility, Australian Synchrotron).

Research infrastructure investment in life sciences is particularly important to establishing effective *biosecurity systems*. Investments in systems biology (Bioplatforms Australia) and collecting and collation of biological data (Integrated Marine Observing System, Terrestrial Ecosystems Research Network (TERN), Atlas of Living Australia (ALA)) strongly support biosecurity activities, and should be maintained. Biosecurity research, especially *food security*, is also heavily dependent on plant and animal phenomics capabilities (Australian Phenomics Network, Australian Plant Phenomics Facility).

There are a variety of programs focusing on *countering crime and extremism* and programs to address perceived disadvantage between races. However, there is no current infrastructure designed to support the development of a comprehensive and robust investigation of the socio-cultural factors that directly impact on issues such as transnational crime and terrorism from either a regional or national perspective.

The Australian Urban Research Infrastructure Network will provide valuable information on understanding of urban resources as well as their use and management to enable better analysis of urban issues, which will impact on Safeguarding Australia research activities concerning *infrastructure* protection.

In recent years the Commonwealth has made substantial investments in better managing and using *geo-spatial* data. TERN, ALA, AuSCOPE and the new supercomputing facility at the Australian National University which is shared by Bureau of Meteorology (BoM) are examples, among others. In addition, the Department of Defence, Geoscience Australia, BoM and others are looking to cooperate more closely than ever before on divisions of effort and responsibility and on stewardship of and access to particular databases. All of these initiatives need certainty of continuation of funding to become properly grounded in the national research infrastructure.

4.E.1	*What are your views on the cross-disciplinary requirements identified, including their relative priority and ability to support the current and future research needs?*

Section F: Current developments

Biosecurity operational management has recently been the subject of a major national review, *One Biosecurity – a working partnership*[24] (The Beale Review). This foreshadowed the need for a significant increase in resourcing both from the private and public sector (more than $260 million per annum) in biosecurity. This

[24] http://daff.gov.au/__data/assets/pdf_file/0010/931609/report-single.pdf

report whilst primarily focussed on operational management did identify pre-border risk assessment and reducing risks from imports.

The Prime Minister's Science, Engineering and Innovation Council released the *Australia and Food Security in a Changing World*[25] report in October 2010, detailing future challenges in maintaining and enhancing Australia's food security, and included biosecurity as a key element.

Significant State Government investment in biosecurity capabilities in New South Wales, Queensland and Victoria focussing on animal and plant based laboratories, containment facilities and biosecurity information systems. Similarly investments in human health biosecurity include the establishment of centres for emerging infectious diseases in New South Wales, Queensland and Victoria.

Geospatial and space technologies

The Space Policy Unit (SPU), formed in 2009, is developing a national space policy, an element of which will almost certainly be a research component. Early indications are that the Australian Space Research Program, coordinated by the SPU, has already fostered very useful collaborations between a number of Australian and international research organisations, agencies and companies. Australia sits in what is known as the Global Navigation Satellite Systems (GNSS) 'hotspot' where all of the current and proposed GNSS systems are visible and this unique geography provides opportunities for Australian researchers.

Cyber-infrastructure

The Australian Government is increasing focus on cyber infrastructure and cyber-security, through the establishment of the national computer emergency response team (CERT Australia) and the Cyber Security Operations Centre within the Defence Signals Directorate. The Attorney-General's Department also co-sponsored the development of the Kokoda Foundation report: *'Optimising Australia's Response to the Cyber Challenge*[26]*'* released in February 2011 acknowledges the need for an integrated whole-of-government approach on cyber security. The Australian Government released a discussion paper in February 2011 outlining its intention to accede to the Council of Europe Convention on Cybercrime[27].

Defence Science and Technology Organisation

DSTO is continuing to invest in defence-related national security research infrastructure, some of which may be applicable to the non-defence national security research community. Programs such as the Defence Science Access Network, DSTO involvement in Cooperative Research Centres, and the Capability and Technology Demonstrator Program are examples of DSTO's increasing willingness to collaborate on defence research projects.

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[25] http://www.chiefscientist.gov.au/wp-content/uploads/FoodSecurity_web.pdf
[26] http://www.kokodafoundation.org/Resources/Documents/KP14ResponsetoCyber.pdf
[27] http://www.ag.gov.au/www/agd/agd.nsf/Page/Consultationsreformsandreviews_ProposedAccessiontotheCouncilofEuropeConventiononCybercrime

Other considerations – Access to defence research infrastructure

The EWG discussed a number of policy considerations that, while related to the efficient and effective use of research infrastructure, were not directly related to the Roadmap discussion paper activities.

The issue considered important enough for discussion as part of the Roadmap is the role of access to defence and classified research infrastructure in the Safeguarding Australia NRP context.

Managing the interface between classified and open research is an unavoidable challenge when addressing the Safeguarding Australia NRP. Ultimately, defence research infrastructure is funded by the Department of Defence to meet defence needs that cannot be serviced elsewhere. The EWG notes, however, that increasing communication on potential avenues for collaboration between the defence and non-defence research communities may be beneficial.

4.F.1	*Are there other programs/issues/developments not listed that you consider could be a driver for future research infrastructure investments or may impact on such investments?*

Understanding Cultures and Communities Expert Working Group

> 'My aim in innovation is not to flood the country with shiny gadgets, but to change the culture. Of course we will need new technologies to answer the challenges and grasp the opportunities that lie before us. But we will also need new institutions, new forms of community – new ways of understanding ourselves and our world. In all of this, the humanities, arts and social sciences are critical.'
>
> *– Senator the Hon. Kim Carr, Minister for Innovation, Industry, Science and Research, 3 September 2008*

Australian researchers are recognised internationally for delivering solutions to the most complex and challenging questions facing cultures and communities. Their contributions are vital to the nation's social wellbeing. Encompassing the study of society, identity, economy, business, governance, history, culture and creativity, this broad field links universities, government agencies, collecting institutions and creative industries with policy development and with communities. However, complex issues of national and global significance cannot be solved in isolation.

They demand collaborative approaches which in turn require the infrastructure to support them. Across all sectors, research practices are being fundamentally influenced by leading-edge ICT, and social and cultural data of immense significance is being generated in many different forms. With considerable investment worldwide in eResearch infrastructure, innovation in the humanities, arts and social sciences is increasingly dependent on enabling technology to support research excellence.

This chapter discusses a possible distributed national eResearch facility to underpin transformational Australian research that will advance our understanding of cultures and communities. This connected online knowledge network would be accessible directly via researchers' desktops. It would revolutionise research in this fundamentally important field by providing integrated services and tools to create, capture, store, share, manage, manipulate and analyse diverse data collections and resources, and it would link individuals with virtual research communities. Such a facility would significantly scale up the capacity of Australia's social and cultural research sector, dramatically increasing its ability to offer solutions to complex global challenges.

Section A: Future research directions

Australia faces critical challenges in the coming decade. Issues of social, economic and cultural sustainability are interrelated with the issues of environmental sustainability that confront our communities daily. In tackling these large-scale concerns, social and cultural researchers are drawing upon deep disciplinary expertise. They are also increasingly working across and beyond traditional boundaries, both national and disciplinary, collaborating with technical experts and scientists to address problems from multiple perspectives.
Research policy in developed economies emphasises the flow-on benefits of investment in the humanities, arts and social sciences and the key role this sector

plays in identifying and formulating solutions to pressing national and global matters[28]. Complex problems in health, the environment or social cohesion can only be addressed through a holistic approach, requiring researchers from the natural sciences and from the humanities, arts and social sciences to work together, drawing on a very wide variety of data types from a diverse range of sources. This in turn drives the need for systems to underpin this approach.

As the trend towards multidisciplinary and multinational collaboration increases as a means to solve complex problems of global significance, an important step in planning future research directions is the identification of priority areas to be supported by investment in research infrastructure under the Understanding Cultures and Communities Capability. Suggested areas with a level of significance and complexity that demands large-scale infrastructure support include:

- Social cohesion, diversity and equity;
- Population change;
- Health and wellbeing;
- Identity and community;
- Indigenous knowledge and opportunity;
- Sustaining culture and creativity;
- Adapting to a changing environment;
- Regional connection and transformation; and
- Strengthening global engagement.

5.A.1	*What are your views on the key future research directions identified and are there other key areas that have not been included?*
5.A.2	*How should we prioritise research areas for this sector when developing Australia's research infrastructure?*

Section B: Research infrastructure Capability areas

An eResearch infrastructure Capability supporting the humanities, arts and social sciences was outlined in the 2008 Roadmap but was not ultimately funded. The Capability featured two broad and connected elements of eResearch infrastructure:

(1) data creation – through digitisation, systematic capture of 'born digital' materials, and support for national survey instruments; and

(2) data management – including curation and dissemination through coordinated strategies and platforms.

In Australia there is now an unmet and growing demand for enabling technology solutions. In the United States and Europe, by contrast, major infrastructure investments in the social and cultural research sector have been made in the past

[28] As Canadian research has demonstrated, whereas the economic benefits of Science, Technology, Engineering and Mathematics (STEM) research are clearly evident within a goods-based economy, a knowledge-based economy derives greater benefit and fosters innovation more effectively, when research in the humanities, arts and social sciences is supported appropriately (see http://www.sshrc-crsh.gc.ca/about-au_sujet/publications/impacts_e.pdf).

five years. Substantial funding is needed to bring our supporting infrastructure to a standard which will facilitate a critical degree of multidisciplinary integration and underpin significant international contributions.

While the conceptualisation and scope of the 2008 Capability remains relevant to present initiatives, new technological possibilities allow us to better define immediate needs and longer-term directions. Access to diverse sources of data in an integrated and cost-effective manner is a key priority. A national eResearch facility would provide a distributed national online environment and the tools needed for interacting and collaborating, and for generating, discovering, accessing, working with and publishing data, regardless of physical location or format. Data in this sector exists in a plethora of formats, many of which are currently very difficult to align for the purpose of meaningful analysis. Bringing together nationally important data collections and resources would ensure that relevant data is (a) more accessible, visible and useable across data sets and repositories; (b) more consistent, uniform and accurate; (c) captured and managed to international standards; (d) generated, deposited and accessed efficiently; and (e) made available in appropriate formats for advance analysis.

Much data of interest to researchers engaged with understanding cultures and communities remains in individual repositories in analogue form and in some cases this may necessitate transfer to appropriate digital formats. A one-size-fits-all approach cannot deal adequately with this level of complexity. While we can learn from the experience of existing Capabilities, with some elements adapted for our use, addressing the research needs of this sector will require purpose-designed infrastructure.

5.B.1	*What are your views on the research infrastructure Capability areas identified, including their relative priority and their ability to support the current and future research needs?*

Section C: Current investments

In the absence of a funded Capability area supporting the humanities, arts and social sciences there has been very limited NCRIS, EIF and Super Science research infrastructure investment catering to this sector. Only two substantial projects have been funded through Super Science and NCRIS, respectively – the Australian Urban Research Infrastructure Network (AURIN), focusing on urban resource use and management, and ASSDA Services for eSocial Science (ASeSS), which aims to improve data archive management and practices within the social sciences and provide simplified access and analysis capabilities across social science archives. Brief descriptions of these projects are provided in **Attachment C**.

At a smaller scale, the AustLit and AusStage projects undertaken through the National eResearch Architecture Taskforce (NEAT) will provide some infrastructure for the Australian literature and performing arts research communities.

Underpinning these undertakings are the much broader NCRIS and Super Science investments in eResearch infrastructure in high performance computing, visualisation and modelling, data storage, advanced networks, data discovery and re-use, collaboration tools and services, along with authorisation and authentication systems.

The Australian Research Council (ARC) Linkage Infrastructure and Equipment Fund (LIEF) is another important basic source of infrastructure funding. However, the scheme is not designed to meet the growing needs of social and cultural research in Australia. Some examples of projects supported in the period 2006-2011 include the various phases of AustLit, humanities eResearch infrastructure for literary and narrative studies, access to the European law collection, the Australian Women's Archive, the Australian Dictionary of Biography Online, AusGate (digital technologies for live performances) and Australian Policy Online. It is notable that the success rate of LIEF grants awarded to the Humanities and Creative Arts (HCA) and Social, Behavioural and Economic Sciences (SBE) sectors combined in 2006-2011 was only 16.5 per cent, translating to just 6.3 per cent of total funds awarded.

Taken overall, the current investments in research infrastructure catering for the needs of the humanities, arts and social sciences are inadequate, being generally *ad hoc* and largely unconnected – both factors inimical to collaborative, multidisciplinary research in complex subject areas. Researchers require infrastructure solutions appropriate to the research practices in this sector and to the data which they generate. They also urgently require effective and efficient interconnections with international research communities and the data they produce and utilise. At stake is the capacity of current and future generations to be globally engaged and productive. Current investments do not meet the current needs nor go substantially towards the future needs of the sector.

5.C.1	*What are your views on the existing funded facilities, including their ability to meet the current and future research needs?*

Section D: eResearch infrastructure needs

Australia has a wide range of data collections and digital resources that play a crucial role in our understanding of cultures and communities. Internationally respected projects such as the Australian Dictionary of Biography, AustLit and Pacific And Regional Archive for Digital Sources in Endangered Cultures (PARADISEC) are examples. However, these collections and resources are dispersed amongst multiple locations, institutions and agencies, and they mostly take the form of stand-alone, subject-specific repositories with very different information architectures. Researchers working collaboratively using digital tools and services to address pressing issues of national and global significance require access to complex data sets that are interoperable. In order to identify, manage and improve these nationally important collections, and make them accessible and usable, it is necessary to develop standards, services and environments through a nationwide approach and on a vastly expanded scale.

A possible eResearch facility could systematically integrate and consolidate our nation's most significant data collections and resources. Underpinned by an infrastructure that allows for sophisticated collaboration and sharing of data, such a facility would allow researchers to access, store and manipulate data in quantitative and qualitative forms – including statistical data, official records, cultural content and web content (for example, Australian Bureau of Statistics information, demographic records, other longitudinal data, and data from libraries, museums, archives and major national projects). In some areas digitisation will be called for to keep abreast of global developments and progress. In other areas data may need to be collected or collated to fill gaps, or else existing data collections may need improving to facilitate interoperability, access and discoverability.

Current initiatives such as the Australian National Data Service (ANDS) offer a mechanism to start joining together such collections and resources, but achieving the desired degree of interoperability will involve much preparatory work. Data must be stored in repositories that provide persistent locations and be described using standard metadata terms. Although ANDS provides collection-level catalogue entries, the social and cultural research sector would benefit from more fine-grained metadata and an ability to view the data itself online. Each repository would require appropriate systems for the management of IP issues and publication of items in its collection. ANDS and Australian Research Collaboration Service (ARCS) already provide a model of a controlled single sign-on system for users. We can be confident that appropriate access and use of the material can be facilitated.

There are many kinds of data relevant to the understanding of cultures and communities that would be made accessible through an eResearch facility, including data as diverse as statistics, oral histories, music, film and text. These exist in various media formats, and this has implications for storage, description and online deliverability. While emerging technologies are offering technical solutions, researchers also need guidance and support. Providing hardware and software in itself is not sufficient. Promoting education and training for 21st century social and cultural research underpinned by ICT is crucial in building the necessary core competencies, domain specific skills and best practices.

5.D.1	*What are your views on the eResearch infrastructure identified, including their relative priority and ability to support the current and future eResearch infrastructure needs of this sector?*
5.D.2	*Are there other eResearch infrastructure needs for the social and cultural research community that have not been identified?*
5.D.3	*Is there a need for a physical or virtual centre for advice and support for the Understanding Cultures and Communities Capability area?*
5.D.4	*For future development of possible infrastructure, can you add to the list of exemplary Australian digital research projects in this sector?*
5.D.5	*Can you provide examples of important, currently distributed collections that could be unified by use of the suggested infrastructure?*
5.D.6	*Can you provide examples of research resources that are currently inhibited by lack of interoperable data and the ability to link to existing research repositories?*

Section E: Cross-disciplinary needs

Each of the current National Research Priorities identifies research from the humanities, arts and social sciences as a key goal. However, research infrastructure to maximise the benefits and reach of the major outputs of the social and cultural sector is yet to be substantially supported. Appropriately resourced, the Understanding Cultures and Communities Capability will address this deficiency. Cross-Capability integration should be sought where possible, to enable social and cultural research to feed directly into problem-solving within the domains of science, health, border security, or other priority areas, and more broadly to enhance investment in and synergies between existing Capabilities[29].

Several of the facilities created under NCRIS, EIF or Super Science investment programs for scientific research have already demonstrated a capacity to support projects from multiple disciplines[30]. These projects indicate the potential to extend data capture and exposure, data processing and analytical services to other research communities. Examples include the Australian Microscopy and Microanalysis Research Facility and other 'characterisation' facilities, ANDS and National eResearch Collaboration Tools and Resources (NeCTAR), as well as underpinning data networking provided through the National Research Network (NRN) and the Australian Research and Education Network (AREN). Existing Capabilities, such as the Atlas of Living Australia, are also potential models.

5.E.1	*What are your views on the cross-disciplinary requirements identified, including their relative priority and ability to support the current and future research needs?*

Section F: Current developments

In Australia there is a very limited number of humanities, arts and social sciences projects of a scale which would have a major influence on future research infrastructure investments. However, Australia is not alone in its need for robust enabling technology solutions to support advanced research in the social and cultural sector and large-scale investments are being made internationally.

In Europe, for example, the European Strategy Forum on Research Infrastructures (ESFRI) has identified a number of projects which aim to provide infrastructure directly aligned with research needs in the humanities, arts and social sciences and has prioritised them for action. Some projects have been funded and are being implemented (e.g. the Council of European Social Science Data Archives, and the European Social Survey Update), while others are funded and are moving towards implementation (e.g. CLARIN [Common Language Resources and Technology Infrastructure] and DARIAH [Digital Research Infrastructure for the

[29] There is a growing number of examples of cross-disciplinary projects designed to address Australia's large-scale problems. Two projects focussing on the risks of climate change impacts that emphasise social research are: the Centre for Water Sensitive Cities at Monash University (http://www.watersensitivecities.org.au/); and the National Climate Change Adaptation Research Facility, funded by the Department of Climate Change and Energy Efficiency (http://www.nccarf.edu.au/).

[30] Australian Urban Research Infrastructure Network (AURIN) is one example.

Arts and Humanities]). These are large-scale projects, and the four noted here have a total implementation cost in the order of $275 million.

We have much to learn from the experience of programs and policies worldwide that have grappled with the complexity of dealing with diverse kinds of data and have made recommendations on the best modes of collaboration. Moreover, it is vital that future Australian investments in these areas are complementary to those being made offshore, ensuring maximum compatibility and interoperability.

5.F.1	*Are there other programs/issues/developments not listed that you consider could be a driver for future research infrastructure investments or may impact on such investments?*

Publications which should be consulted in conjunction with this chapter.

Documents specifically related to the infrastructure requirement of the humanities, arts and social sciences:

European Commission, FP7 Socio-economic Sciences and Humanities, Indicative Strategic Research Roadmap (2011-2013), 2009
http://ec.europa.eu/research/social-sciences/pdf/roadmap-2011-2013-final_en.pdf

European Commission, Emerging Trends in Socio-economic Sciences and Humanities in Europe, the METRIS (Monitoring European Trends in Social Sciences and Humanities) report, 2009
http://ec.europa.eu/research/social-sciences/pdf/metris-report_en.pdf

ESFRI (European Strategy Forum on Research Infrastructures) European Roadmap for Research Infrastructures, Social Sciences and Humanities Roadmap Working Group Report, 2008
http://ec.europa.eu/research/infrastructures/pdf/esfri/esfri_roadmap/roadmap_2008/ssh_report_2008_en.pdf

ESFRI (European Strategy Forum on Research Infrastructures) European Roadmap for Research Infrastructures, Report of the Social Sciences and Humanities Working Group, September 2006
http://ec.europa.eu/research/infrastructures/pdf/esfri/esfri_roadmap/roadmap_2006/ssh-rwg-roadmap-report-2006_en.pdf

Key European Roadmap for Research Infrastructure reports:

ESFRI (European Strategy Forum on Research Infrastructures) European Roadmap for Research Infrastructures, Implementation Report 2009
http://www.europarl.europa.eu/meetdocs/2009_2014/documents/itre/dv/esfri_implementation_report_2009_/esfri_implementation_report_2009_en.pdf

ESFRI (European Strategy Forum on Research Infrastructures) European Roadmap for Research Infrastructures, Update 2008
http://ec.europa.eu/research/infrastructures/pdf/esfri/esfri_roadmap/roadmap_2008/esfri_roadmap_update_2008.pdf

ESFRI (European Strategy Forum on Research Infrastructures) European Roadmap for Research Infrastructures, Report 2006
http://ec.europa.eu/research/infrastructures/pdf/esfri/esfri_roadmap/roadmap_2006/esfri_roadmap_2006_en.pdf

Other relevant documents:

Sustainable Economics for a Digital Planet: Ensuring Long-Term Access to Digital Information, Final report of the Blue Ribbon Task Force on Sustainable Digital Preservation and Access, February 2010
http://brtf.sdsc.edu/biblio/BRTF_Final_Report.pdf

Trends in European Research Infrastructures: Analysis of data from the 2006/07 survey, European Commission, European Science Foundation, Report, July 2007
http://ec.europa.eu/research/infrastructures/pdf/survey-report-july-2007_en.pdf

Our Cultural Commonwealth, The report of the American Council of Learned Societies Commission on Cyberinfrastructure for the Humanities and Social Sciences, 2006
http://www.acls.org/cyberinfrastructure/ourculturalcommonwealth.pdf

eResearch Infrastructure Expert Working Group

eResearch has the potential to increase the efficiency and effectiveness of research across all disciplines, offering the potential for new paradigms of research capabilities and allowing research that otherwise would not be possible.

eResearch is currently enabling Australian researchers in fields as diverse as climate, astronomy, medicine, genetics, chemistry, education, geoscience, linguistics and finance to achieve high quality research outcomes and to disseminate knowledge gained from research through the use of advanced ICT.

eResearch can now be seen as the cornerstone of modern research by providing:

- increasingly powerful computer-enabled simulations and modelling currently necessary in some fields and increasingly necessary in many others; and
- an avenue to manipulate, manage, share and integrate the increasing volume and complexity of datasets and collections. The insights from shared data sets will drive the next generation of innovation.

The 2008 *Strategic Roadmap for Australian Research Infrastructure* (2008 Roadmap) conceptually aligned the eResearch infrastructure capacity required by the research sector into three categories of need:

1. Infrastructure that enables new research and new forms of research, including high performance communications networks, high performance computing facilities, software tools and workflows, data storage, and resource access and authentication systems.
2. Infrastructure that helps effect the transition to eResearch, including data federation and collaboration, such that researchers are able to work more effectively and easily with each other and in ways they had not previously imagined.
3. Improved governance and expertise to ensure that personnel with the necessary skills and experience are available to drive and deliver these services and tools.

Building on this characterisation, the discussion in this chapter has considered the underpinning, pervasive ICT infrastructure requirements needed to support all research and research collaboration. In particular, respondents to the discussion paper are asked to consider:

- how the current vision for eResearch infrastructure in the 2008 Roadmap needs to be modified, built upon and extended particularly looking out for the next 10 years;
- future infrastructure requirements and demands, and if there are changing ways the various elements should and could be coordinated;
- the human capability required to operate such infrastructure; and
- the most appropriate approaches to build awareness and skill level across the Australian research community.

Respondents are also asked to keep in mind not only the eResearch infrastructure that has already been built, but the significant amount of new infrastructure under development and construction that will be completed in the next two to three years.

Section A: Trends

The categories of need identified above for eResearch infrastructure continue to be required by the research sector. However, it seems increasingly likely that this need will continue to expand at rates higher than previously considered.

This will create opportunities to not only support priority research areas identified in the 2008 Roadmap but to generate a step change across the research sector through the adoption of eResearch across broader disciplines and, in particular, revolutionise research into the social sciences and humanities.

Some of the drivers of these developments include the:

- analysis of increasingly large data sets by high-end simulation and modelling procedures implemented on high performance computing (HPC) platforms;
- need for the digital curation of increasingly large data sets;
- increasing reliance on the collaborative sharing of data and research results between national and international participants;
- need for new tools to support the analysis and reuse of data; and
- support for the emergence of alternative approaches to research workflows including considerations of electronic notebooks, and emerging complexities of using these tools driven by legal compliance and industry accreditation necessary to provide non-repudiation of experimental results.

A significant trend is the dramatic growth in research data with the amount of data now expected to double at least every five years. Previously, the rate of data growth was matched by a relative decline in the rate of data storage costs. However, the rate of data growth has now outstripped the rate at which storage costs have been reducing. The scale of data storage now required, and required into the future, will therefore have sustainability implications.

At the same time, scientific instruments and 'streaming' devices will increase the trend towards processing multi- media data. Processing these kinds of data will impact on the approach taken to provide data repositories, security approaches and data management as will the emerging requirements for the publication of all data resulting from publically funded research.

Operational and cost efficiencies inspired in part from the increasing power costs of peak HPC capabilities and need for green computing have recently led to advances in cloud computing. This growth is expected to accelerate over the next five years as more researchers take up these tools. As advances in this area progress, issues associated with interoperability between public (and private) clouds will need to be addressed.

The need for appropriately secure, open and user-friendly access to eResearch infrastructure will accelerate over the next five to ten years through a focus on user-centred design methodologies and approaches which allow researchers to manage their collaborative research environment and enable them to seamlessly move from and between desk-top computing, high performance computing and cloud computing.

The increased costs of large-scale international experiments and computational facilities has implications for the dependency of Australia on overseas facilities and hence there will be a need for international connectivity, research services and data networks.

In the context of building an eResearch Infrastructure capability that enables 'everyone and everything' to be connected, there will also be more demand for interactive interfaces. This may be driven by disasters and catastrophes (such as floods, earthquakes, fires and security), and from productivity gains (real-time data analysis from experiments).

In addition, as trends towards the automation of facilities and more direct access by researchers to these facilities continue, the need for workflows and portals and access to highly skilled and specialised research capability and services will increase. In the future, these interfaces may become more like social networks supporting many communities of specialised research interest.

Beyond the needs in currently identified research areas, such as climate science and astronomy, accelerated investment may be required in the following:

- computational and simulation science;
- imaging, characterisation and visualisation; and
- ubiquitous deployment of wireless sensor networks. Urban research is one example of interdisciplinary research that needs to take into account social, cultural and infrastructure - transport, energy and water – requirements, which are dependent on the availability of sensor networks.

6.A.1	*Do you agree that the trends identified reflect the future eResearch directions? Are there any others?*
6.A.2	*What areas do you expect to increase their reliance or would benefit from increased reliance on eResearch infrastructure in the future?*
6.A.3	*Can you identify any other research areas or trends that currently have or will have a high use or reliance on eResearch infrastructure and related technologies?*
6.A.4	*Are there opportunities that you see emerging from trends in e-Research that we need to consider?*

Section B: Current eResearch infrastructure investments and medium term future

eResearch infrastructure investments in high performance computing, visualisation and modelling, data storage, advanced networks, data discovery and re-use, collaboration tools and services and authorisation and authentication systems are all necessary elements in the creation of a comprehensive eResearch fabric.

The Australian Government has been working to addressing these requirements, to differing degrees, through $82 million of funding under NCRIS and $312 million of funding under the Super Science Initiative.

Together the NCRIS and Super Science investments have enabled the development of an eResearch infrastructure backbone that supports researchers across the country, and in their collaborations with colleagues and institutions, both domestically and internationally.

This has included targeted funding support for:

- High Performance Computing, visualisation and modelling supported by investment in the National Computational Infrastructure (NCI), investment in High Performance Computing for Climate Research and Pawsey High Performance Computing Centre for SKA Science;
- digital data storage supported by investment in the Research Data Storage Infrastructure (RDSI) Project;
- advanced networks supported by ongoing investment in the Australian Research and Education Network (AREN);
- data discovery and re-use supported by investment in the Australian National Data Service (ANDS), the Australian Research Data Common (ARDC) and ASSDA Services for eSocial Sciences Project (ASeSS);
- collaboration tools and services supported by investment in the Australian Research Collaboration Service (ARCS) and the National eResearch Collaboration Tools and Resources (NeCTAR) Project; and
- authorisation and authentication systems through investment in the Australian Access Federation (AAF).

Further funding details of the projects listed above can be found at **Attachment B** of this paper.

Funding for projects under NCRIS ceases in 2011, while the Super Science Initiative concludes in 2013. As a result, some of the impacts from these investments are yet to be fully felt by the research sector.

To date, the key advances have been in the near-ubiquitous deployment of high bandwidth research networks, through the Australian Research and Education Network, and in the demand for, and uptake of, high performance computing.

The impact of the former has relevance for almost every researcher and is essential for basic to advanced research, whereas the latter has relevance for a small but growing set of disciplines.

In the area of data management, a focus on supporting universities will hopefully result in more widespread understanding and uptake of data management practices.

Except for authorisation services and tools, the impact of investments in collaborative tools and resources on researchers is yet to be fully realised and ascertained.

These national investments complement, and have supported, the development of state and territory and institution based eResearch capabilities.

6.B.1	*Do you consider that the current and medium term eResearch infrastructure investments are meeting the current and future needs identified in this chapter and are there any gaps?*

Section C: eResearch infrastructure requirements

eResearch infrastructure refers not only to the *hardware* that enables research but also the *software applications* that facilitate research and the *people* with the skills and capacity to build and maintain this spectrum of systems.

Below are a series of potential requirements that overlap across these areas to generate feedback and input:

Sustainability

- Long term certainty of investment in eResearch that emphasises the linkages between eResearch capability across the research sector and into government and business;
- Strong and enduring coordination and governance of the building, delivery and maintenance of hardware, software and collaborative infrastructure;
- Certainty of long-term maintenance and accessibility including 24/7 support; and
- The creation of a flexible and responsive skills capability including an assessment of what specialist capabilities are required to support eResearch infrastructure investments.

Access and penetration

- Ready access to common infrastructure and storage;
- Solutions to security, robustness and accessibility issues;
- Resolving data ownership issues including requirements for publically funded data and tools to be made available;

- Facilitating the use by researchers of data that was collected primarily for purposes other than research, including data generated or held by government or industry (which will include addressing the associated issues such as privacy);
- removal of impediments which limit the implementation of new technologies into the research environment including methods to ensure penetration of new technologies down to the researcher level and also from the individual back to the research community as a whole;
- Data portals designed for the non-IT user to support data systems;
- Expanded reach and capacity of the AREN to support growth in international capacity with a likely focus on links into South East Asia;
- A shift in investment in the AREN from large capital works (fibre builds) with 20+ year lifetimes to planned procurements of active equipment with a three to five year life and a focus on higher level 'overlay' networks implemented on existing infrastructure to meet specific research demand; and
- Recognition that significant growth in mobile networks will present new and qualitatively different opportunities for individual researchers to be connected, allowing opportunities for sensor networks and citizen science to grow.

Determining priorities

A number of challenges present themselves in undertaking a strategic assessment of the required investments be undertaken. For example, the assessment would need to:

- balance the high end high performance computing needs of some disciplines, against
- the needs of a large number of disciplines for access to much more basic but similarly transitional eResearch Infrastructure such as collaboration tools and resources.

This balance needs to be informed by the infrastructure requirements driven and directed by individual research communities combined with that determined and provided by the ICT research community.

In addition, how could sector-wide governance be improved to facilitate the detailed and consistent capacity and operational planning required to optimise eResearch investments made at the national scale?

Beyond the potential requirements outlined above, specific eResearch infrastructure needs can also be highly discipline-dependent. Similarly, the awareness of the potential for eResearch and the gains to be obtained from accessing eResearch infrastructure varies from discipline to discipline.

Some areas, such as astronomy, molecular biology, climate science and some areas of physics, can only advance with the very latest high performance computing supported by high quality network capacity and data storage.

It seems certain that many of these research communities will need to transition to exascale computing by the end of the decade to remain internationally relevant. Australia should develop its own exascale capacity or consider whether it should partner internationally to enable access to such a capacity for the country's researchers.

There are major challenges in strategic planning for eResearch infrastructure. One particular challenge is the need to balance investments to support high end users while also providing the e-fabric that will lift the participation of those disciplines that are relatively late adopters of eResearch.

Also important is the need to ensure that the eResearch infrastructure that is built is flexible enough to support new and emerging priority areas while also supporting the adoption of new technologies.

Perhaps the most crucial challenge is the change in approach required to enable a deep integration of eResearch across Australia's research community.

Understanding this cultural challenge and developing coordinated strategies to enable a cultural shift is key, particularly given that many organisations do not have an eResearch strategy that is adaptable, adequately resourced and implemented.

6.C.1	*What are your views on the eResearch infrastructure requirements identified, including their relative priority, their ability to support the current and future research needs and whether there are any gaps?*
6.C.2	*What are your views on the issue of prioritising between eResearch infrastructure to support individual disciplines/Capability areas and more generic underpinning eResearch infrastructure?*

Section D: Drivers, Impediments and Barriers

Powering Ideas: an innovation agenda for the 21st Century identified that driving world class research across the national innovation system requires both strong agents, and strong links between agents[31]. If this characterisation is true, appropriate links between agents (for example between universities, the Australian Research Council and Australian governments) must be fostered that assist in supporting drivers and the removal of impediments that prevent the uptake of eResearch and the use of eResearch infrastructure.

Outlined below are some observations of possible drivers, impediments and barriers, which are by no means exhaustive, to prompt discussion and feedback.

[31] *Powering ideas: an innovation agenda for the 21st century* (2010) Retrieved March 2010 from http://www.innovation.gov.au/Innovation/Policy/Pages/PoweringIdeas.aspx

Collaboration

Collaboration is an essential component of an effective national research and innovation system. However, competition remains the primary critical mechanism for obtaining research grants and ensuring research excellence. Are we driving competition and collaboration in appropriate ways?

Collaboration across agencies responsible for funding both research activity and research infrastructure is also required. How do we ensure appropriate alignment of the policy and funding drivers to deliver the optimum national research and innovation outcomes?

To manage complexity at a national level, multiple national agencies have been created to deliver eResearch Infrastructure, each with their own priorities, programs, funding allocation processes and outreach activities.

There are also a variety of agencies at a state level, and service providers of many different types evolving within research institutions themselves. How might we deal with the challenges of working across boundaries? What has worked well in this approach? How could the approach be improved?

Lynch[32] noted that investments in campus eResearch infrastructure and national eResearch infrastructure should be not just complementary but mutually reinforcing. He highlighted the need for local investment if a research institution is to be able to fully benefit from national investments. Are there barriers or impediments to ensuring this complementarity?

Supporting data

Research data is now recognised as a critical component of research infrastructure. The Australian Code for the Responsible Conduct of Research[33] encourages researchers to make their research data available to other researchers, and encourages institutions to permanently retain research data of community or heritage value. However, strong disincentives remain to limit the engagement of researchers and institutions with long-term data management.

Sustainability

The implementation of eResearch infrastructure investment has, to date, occurred via a number of funding sources and models. Sustainability and continuity of funding are important to discussions about Australia's research productivity and in facilitating the ubiquitous shift towards eResearch across the research sector. What are the models and approaches that could be used to ensure sustainability and certainty?

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[32] Lynch, C. (2008) The institutional challenges of cyberinfrastructure and e-research. *EDUCAUSE Review* Nov/Dec 2008, pp.74-88

[33] The Australian Code for the Responsible Conduct of Research (2007) Retrieved March 2011 from http://www.nhmrc.gov.au/_files_nhmrc/file/publications/synopses/r39.pdf

Human capital

The 2008 Roadmap outlined lessons for future program implementation[34] and highlighted the need to develop capabilities, skills and expertise and the need for continued cultural change if we are to optimise the benefits of national investment in research infrastructure.

However, the vast majority of national investment has been in infrastructure, rather than in the 'human middleware' required to maximise the benefits from this investment. Better understanding the impact of this situation will be important to framing how we develop capacity and work to achieve longer-term cultural change. What has been the impact of this? How do we develop the capabilities and achieve the cultural change we had hoped for?

6.D.1	*What are the barriers to successfully building an effective national eResearch infrastructure?*
6.D.2	*What would encourage researchers/institutions/capabilities to participate in the eResearch vision?*
6.D.3	*What aspects of the current eResearch infrastructure developments have worked well and why?*
6.D.4	*What is the role of institutions in supporting eResearch infrastructure in the context of a national eResearch infrastructure agenda?*

[34] Strategic Roadmap for Australian Research Infrastructure, August 2008 retrieved March 2011 from https://www.pfc.org.au/pub/Main/WebHome/Strategic_Roadmap_Aug_2008.pdf p. 12

Attachment A – Members of Expert Working Groups

Environmentally Sustainable Australia

Dr John Gunn (Chief Scientist, Australian Antarctic Division) – Chair
Professor Vassiliios G Agelidis (The University of New South Wales)
Dr Andrew Barnicoat (Geoscience Australia)
Dr John Church (CSIRO)
Dr Colin Creighton (Fisheries Research and Development Corporation and the Grains Research and Development Corporation)
Dr Nick D'Adamo (UNESCO)
Professor David Day (Flinders University)
Professor Stephen Dovers (The Australian National University)
Professor Bronwyn Gillanders (The University of Adelaide)
Mr Warwick McDonald (Bureau of Meteorology)
Dr Phillip McFadden
Dr Neil McKenzie (CSIRO)
Dr Tony Press (Antarctic Climate and Ecosystems Cooperative Research Centre)
Dr Russell Reichelt (Great Barrier Reef Marine Park Authority)
Professor Paul Sanders (Queensland University of Technology)
Professor Mike Sandiford (The University of Melbourne)
Dr Brett Summerell (The Royal Botanic Gardens and Domain Trust)
Professor Grant Wardell-Johnson (Curtin University)

Promoting and Maintaining Good Health

Professor Mike Calford (Deputy Vice-Chancellor (Research), The University of Newcastle) – Chair
Professor Judith Clements (Queensland University of Technology)
Professor Simon Foote (University of Tasmania)
Dr Paul Jelfs (Australian Bureau of Statistics)
Professor Louisa Jorm (University of Western Sydney)
Professor Paul Keall (The University of Sydney)
Professor Peter Leedman (The University of Western Australia)
Professor Julio Licinio (The Australian National University)
Professor Kerin O'Dea (University of South Australia)
Professor Ian Smith (Monash University)
Dr Ron Weiner (Australian Nuclear Science and Technology Organisation)

Frontier Technologies

Dr Calum Drummond (Group Executive, Manufacturing, Materials and Minerals, CSIRO) – Chair

Dr Phil Diamond (CSIRO)

Professor Lorenzo Faraone (The University of Western Australia)

Associate Professor John Fletcher (The University of New South Wales)

Dr Marie-Claude Gregoire (Australian Nuclear Science and Technology Organisation)

Professor Tanya Monro (The University of Adelaide)

Professor Paddy Nixon (University of Tasmania)

Emeritus Professor John O'Callaghan (The Australian National University)

Professor Mary O'Kane (NSW Chief Scientist and Scientific Engineer)

Professor Bernard Pailthorpe (The University of Queensland)

Professor Steven Prawer (The University of Melbourne)

Professor Judy Raper (University of Wollongong)

Professor Robert Williamson (The Australian National University)

Safeguarding Australia

Dr Alastair Robertson (Group Executive, Food, Health and Life Science Industries, CSIRO) – Chair

Dr Laurie Besley (National Measurement Institute)

Mr Brett Biddington (Biddington Research Pty Ltd.)

Dr Regina Fogarty (Industry & Investment NSW)

Associate Professor James Gilkerson (The University of Melbourne)

Professor Andrew John Goldsmith (University of Wollongong)

Dr John Percival (Defence Science and Technology Organisation)

Professor Susan Pond (Commercialisation Australia)

Dr John Stambas (Deakin University)

Professor Sue Thomas (Charles Sturt University)

Associate Professor Colin Wastell (Macquarie University)

Professor Tony Watson (Edith Cowan University)

Professor John Roddick (Flinders University)

Professor Richard Tay (La Trobe University)

Understanding Cultures and Communities

Professor Rae Frances (Dean of Arts, Monash University) – Chair
Professor Pal Ahluwalia (University of South Australia)
Ms Margaret Anderson (History SA)
Dr Paul Arthur (The Australian National University)
Professor Alison Bashford (The University of Sydney)
Professor Ann Capling (The University of Melbourne)
Mr Alec Coles (Western Australian Museum)
Distinguished Professor Stephen Crain (Macquarie University)
Dr Rebecca Johnson (Australian Museum)
Dr Marcus Lane (CSIRO)
Ms Anne-Marie Schwirtlich (National Library of Australia)
Dr Luke Taylor (Australian Institute of Aboriginal and Torres Strait Studies)
Dr Nicholas Thieberger (The University of Melbourne)
Professor Mandy Thomas (The Australian National University)
Ms Gemma Van Halderen (Australian Bureau of Statistics)
Professor Andrew Wells (Australian Research Council)

eResearch Infrastructure

Professor Attila Brungs (Deputy Vice-Chancellor and Vice-President (Research), University of Technology, Sydney) – Chair
Professor Paul Bonnington (Monash University)
Professor Andrew Cheetham (University of Western Sydney)
Dr Joanne Daly (CSIRO)
Mr Peter Nikoletatos (Curtin University)
Mrs Linda O'Brien (Griffith University)
Professor Andy Pitman (The University of New South Wales)
Mr Antony Stinziani (Geoscience Australia)
Ms Judy Stokker (Queensland University of Technology)
Dr Darrell Williamson (CSIRO)
Dr Judith Winternitz (Department of Broadband, Communications and the Digital Economy)

Attachment B – List of funded research infrastructure capabilities and projects

2008 Roadmap Capability area	Name	Lead organisation	NCRIS Funding (million)*	Super Science Funding (million)	EIF Competitive Funding (million)	Other Funding (million)
eResearch	Australian National Data Service (ANDS) - including Australian Research Data Commons	Monash University	$24.00	$48.00		
eResearch	ASSDA Services for eSocial Science (ASeSS)	The Australian National University	$3.00			
eResearch	Research Data Storage Infrastructure (RDSI) Project	University of Queensland		$50.00		
eResearch	National Research Network (NRN) Project	University of South Australia		$37.00		
eResearch	Australian Research and Education Network (AREN) - Connections in the Northern Territory	AARNet Pty Ltd	$2.96			
eResearch	National Computational Infrastructure (NCI)	The Australian National University	$26.00			
eResearch	Climate High Performance Computing Centre	The Australian National University		$50.00		
eResearch	Pawsey High Performance Computing (HPC) Centre for SKA Science	CSIRO as centre agent for iVEC		$80.00		
eResearch	Interoperation and Collaboration Infrastructure (ICI) - ARCS	Victorian Partnership for Advanced Computing (VPAC), as lead agent for the Australian Research Collaboration Service (ARCS) unincorporated joint venture	$20.50			
eResearch	Authorisation Services - ARCS	Victorian Partnership for Advanced Computing (VPAC), as lead agent for the Australian Research Collaboration Service (ARCS) unincorporated joint venture	$2.00			
eResearch	Australian Access Federation (AAF) Implementation	Queensland University of Technology (QUT) on behalf of the Council of Australian Directors of Information Technology (CAUDIT)				$2.00
eResearch	National eResearch Collaboration Tools and Resources (NeCTAR)	The University of Melbourne		$47.00		

* Some of these amounts have been subject to small adjustments over time
All figures are GST exclusive

2008 Roadmap Capability area	Name	Lead organisation	NCRIS Funding (million)*	Super Science Funding (million)	EIF Competitive Funding (million)	Other Funding (million)
Terrestrial Ecosystems	Terrestrial Ecosystem Research Network (TERN)	University of Queensland	$20.00	$25.63		
Terrestrial Ecosystems	Atlas of Living Australia	CSIRO	$8.23	$30.00		
Terrestrial Ecosystems	Australian Plant Phenomics Facility	The University of Adelaide	$15.24	$10.00		
Built Environments	Australian Urban Research Infrastructure Network (AURIN)	The University of Melbourne		$20.00		
Marine Environment	Marine National Facility	CSIRO	$6.70	$149.60		
Marine Environment	Integrated Marine Observing System (IMOS)	University of Tasmania	$50.00	$52.00		
Marine Environment	Tropical Marine Research Facilities	AIMS		$55.00		
Marine Environment	Sydney Institute of Marine Science (SIMS)	SIMS			$19.50	
Australian Continent	AuScope	AuScope Limited	$42.80			
Australian Continent	Australian Geophysical Observing System - AuScope	AuScope Limited			$23.00	
Australian Continent	Groundwater	University of NSW		$15.00		
Integrated Biological Discovery	Biomolecular Platforms	Bioplatforms Australia Ltd	$50.00	$50.00		
Integrated Biological Discovery	Australian Phenomics Network (APN)	Australian National University	$16.00	$15.00		
Integrated Biological Discovery	European Molecular Biology Laboratory (EMBL) - Associate Membership and Partner Laboratory Network	Monash University	$3.00	$8.00		
Translating Health Discovery Into Clinical Application	Translating Health Discovery	Pt 1 - Monash University - $6.500m Pt 2 - Therapeutic Innovation Australia Ltd (formerly Research Infrastructure Support Services (RISS)) - $28.500m		$35.00		
Translating Health Discovery Into Clinical Application	Biotechnology Products – Recombinant Proteins	AusBiotech Ltd	$13.38			

2008 Roadmap Capability area	Name	Lead organisation	NCRIS Funding (million)*	Super Science Funding (million)	EIF Competitive Funding (million)	Other Funding (million)
Translating Health Discovery Into Clinical Application	Manufacture of Human Cells for Transplant	Therapeutic Innovation Australia Ltd (formerly Research Infrastructure Support Services (RISS))	$7.62			
Population and Biological Health Data Network	Population Health Research Network (PHRN)	The University of Western Australia	$20.00	$10.00		
Characterisation	Australian Synchrotron - beamlines	Australian Synchrotron	$13.91			
Characterisation	International Synchrotron Access Program (ISAP)	Australian Synchrotron	$0.63			
Characterisation	Australian Synchrotron Research Program (ASRP) - access to international facilities	Australian Nuclear Science and Technology Organisation (ANSTO)	$3.57			
Characterisation	National Centre for Synchrotron Science: Outreach and Research Support Facilities	Australian Synchrotron			$36.78	
Characterisation	National Imaging Facility (NCRIS)	The University of Queensland	$7.25			
Characterisation	National Imaging Facility (EIF project)	The University of Queensland			$40.23	
Characterisation	Australian Microscopy and Microanalysis Research Facility	The University of Sydney	$19.10			
Characterisation	National Deuteration Facility	Australian Nuclear Science and Technology Organisation (ANSTO)	$3.25			
Fabrication	Australian National Fabrication Facility	Australian National Fabrication Facility Ltd	$41.00	$50.00		
Optical and Radio Astronomy	Optical and Radio Astronomy	Astronomy Australia Limited (AAL)	$45.53	$10.00		
Optical and Radio Astronomy	Giant Magellan Telescope	Australian National University		$88.40		
A Sustainable Energy Future	Sustainable Energy: Biofuels	AusBiotech Ltd	$7.98	$3.00		
A Sustainable Energy Future	Sustainable Energy: Fusion	Australian National University		$7.00		
Heavy Ion Accelerators	Heavy Ion Accelerators	Australian National University		$10.00		

2008 Roadmap Capability area	Name	Lead organisation	NCRIS Funding (million)*	Super Science Funding (million)	EIF Competitive Funding (million)	Other Funding (million)
Networked Biosecurity	Australian Biosecurity Intelligence Network (ABIN)	Australian Biosecurity Intelligence Network (ABIN)	$16.12			
Networked Biosecurity	Australian Animal Health Laboratory (AAHL)	Australian Animal Health Laboratory (AAHL)	$8.50			
N/A - project	Cairns Institute - Tropical Innovation Hub	James Cook University				$19.50
N/A - project	Daintree Rainforest Observatory	James Cook University		$9.37		
N/A - project	Nuclear Science Facilities	ANSTO		$62.00		
N/A - project	Institute for Marine and Antarctic Studies (IMAS)	University of Tasmania			$45.00	
N/A - project	Indian Ocean Marine Research Centre	University of Western Australia			$34.00	
N/A - project	New Horizons Centre	Monash University			$89.90	
N/A - project	The Institute for Photonics & Advanced Sensing	The University of Adelaide			$28.76	
N/A - project	Australian Institute for Innovative Materials: Processes and Devices Facility	University of Wollongong			$43.80	
N/A - project	Centre for Neural Engineering	University of Melbourne			$17.52	
N/A - project	Centre of Climate Change and Energy Research (CCCER)	University of Western Sydney			$40.00	
N/A - project	La Trobe Institute for Molecular Science (LIMS)	La Trobe University			$64.10	
N/A - project	Smart State Medical Research Centre	Queensland Institute of Medical Research			$55.00	
N/A - project	Sustainable Energy for SKA	CSIRO			$47.30	
N/A - project	Australian Future Fibres Research and Innovation Centre	Deakin University			$37.00	
N/A - project	Australian Institute for Nanoscience	The University of Sydney			$40.00	
N/A - project	Green Chemical Futures	Monash University			$29.12	
N/A - project	Newcastle Institute for Energy and Resources	University of Newcastle			$30.00	
N/A - project	Retrofitting for Resilient and Sustainable Buildings	University of Wollongong			$25.10	

Attachment C – Brief descriptions of funded capabilities

National, collaborative research infrastructure capabilities that are being implemented through NCRIS or Super Science are described below.

An overall description of the eResearch infrastructure investments is provided in Section B of the eResearch Infrastructure Expert Working Group chapter.

ASSDA Services for eSocial Science

The ASSDA Services for eSocial Science (ASeSS) project consists of a data archive component, to improve the curation and archiving of social science data, and a Virtual Organisation component, to provide integrated web based access to ASSDA held and other similarly curated data.

Terrestrial Ecosystem Research Network

The Terrestrial Ecosystem Research Network (TERN) brings together dedicated observation sites, standardised measurement methodologies, equipment, and information services across Australia which collectively will contribute to meeting the needs of terrestrial ecosystem research and natural resource management in Australia.

Atlas of Living Australia

The Atlas of Living Australia (ALA) is an information infrastructure to enable researchers and other users to find, access, combine and visualise data on Australian plants and animals. The ALA will support biological and ecological research by improving the accessibility and usability of Australia's biodiversity and ecological data.

Australian Plant Phenomics Facility

The Australian Plant Phenomics Facility (APPF) provides leading-edge research capability to support the development of new crop varieties to feed an expanding world population. The APPF has two nodes, the Plant Accelerator in South Australia and the High Resolution Plant Phenomics Centre in Canberra. Research networks and established pathways to market will ensure outcomes are delivered for the long-term benefit for Australian scientists and primary producers.

Australian Urban Research Infrastructure Network

The Australian Urban Research Infrastructure Network (AURIN) provides built environment and urban researchers, designers and planners an information infrastructure to facilitate access to a distributed network of aggregated datasets and information services. AURIN will have mechanisms, protocols and tools by which data can be accessed, interrogated, modelled and/or simulated.

Marine National Facility

The Marine National Facility is a blue-water research capability. Funding is being provided to repair and maintain the current blue-water marine research vessel (the *Southern Surveyor),* and to provide a new replacement vessel (the *Investigator)*. The new vessel will be capable of spending more than 300 days a year at sea, supporting activities across a range of disciplines in oceanographic, climate, geological, fisheries and ecosystem research.

Integrated Marine Observing System

The Integrated Marine Observing System (IMOS) is a national-scale, in-situ, ocean observing system. It observes open-ocean to coastal and covers the physical and biological variables to better understanding climate change in Australia. While the NCRIS project has delivered the bulk of the infrastructure and is focusing on uptake and distribution of data, the Super Science Initiative will focus on enhancement and extension of IMOS facilities, the extension of two nodes and the establishment of the Tasmanian node.

Tropical Marine Research Facilities

The Australian Institute of Marine Science (AIMS) is constructing new tropical marine research facilities to support research in the sustainable use and protection of Australia’s marine environment. This includes refurbishment and construction of laboratories, expanding seawater research aquaria facilities, and purchasing and installation of a range of marine research equipment in Townsville and Darwin.

Institute for Marine and Antarctic Studies

The Institute for Marine and Antarctic Studies (IMAS) is a new marine science precinct on the Hobart waterfront which will house an integrated suite of laboratories, offices and amenities to platform Australia's research excellence in temperate water, Southern Ocean and Antarctic marine science.

Indian Ocean Marine Research Centre

The Indian Ocean Marine Research Centre (IOMRC) has been established to provide researchers with state of the art facilities to collaborate their knowledge of ocean science and engineering. In particular, the focus of the centre will be on ocean policy to resource developments and management of marine ecosystems of Australia’s North West coast including in the areas of offshore engineering, biodiversity, ocean policy and maintenance and management of coastal infrastructure.

AuScope

AuScope is enabling an integrated approach to geoscience though investments in technology, data and knowledge infrastructure. The major data acquisition infrastructure comprises of four components: Earth Imaging and Structure; Earth Materials and Properties (the ‘Virtual Core Library’); Earth Composition and Evolution; and AuScope Geospatial Framework and Earth

Dynamics. AuScope further comprises two ICT components: the AuScope Grid and the AuScope Simulator.

Australian Geophysical Observing System - AuScope

The AuScope Australian Geophysical Observing System (AGOS) will augment the existing NCRIS AuScope infrastructure with new capability that focuses particularly on emerging geophysical energy issues. AuScope AGOS infrastructure will enable collection of new baseline data including surface geospatial and subsurface imaging and monitoring data, thereby providing for better long-term management of crustal services, particularly in our energy-rich sedimentary basins.

Groundwater

Groundwater is a long-term groundwater monitoring project that will allow Australian groundwater resources to be evaluated against a background of continuing climate variability and oncoming climate change.

Biomolecular Platforms

Bioplatforms Australia provides services and scientific infrastructure to support life sciences research. The Bioplatforms Australia network includes the following four platform consortia:

- Genomics Australia – high throughput gene sequencing, transcript analysis, epigenetics, bioinformatics
- Proteomics Australia – protein separation, mass spectrometry, monoclonal antibody development, protein chemistry
- Metabolomics Australia – small molecule analysis, sample preparation, metabolite profiling, mass spectrometry, lipodomics
- Australian Bioinformatics Facility –computational tools, bioinformatics strategies, data acquisition, data analysis, data reporting.

Australian Phenomics Network

The Australian Phenomics Network (APN) brings together mouse production, strain storage and pathology capabilities across Australia to provide researchers with mouse models for the study of human and animal disease. The exome analysis capability will be integrated with the other APN capabilities, and with parallel human phenomics capabilities in order to position Australian research at the leading edge of the field.

European Molecular Biology Laboratory

Investment in the European Molecular Biology Laboratory (EMBL) as an associate member, as well as the development of a the EMBL Australia Partner Laboratory Network, has opened avenues of direct access to leading international laboratories and research infrastructure, as well as the development of a dual PhD program.

Translating Health Discovery

The Translating Health Discovery (THD) project will address research infrastructure-related issues in the translational landscape including the research stage, manufacturing of products for trials (e.g. microbial, human and animal cell products), pharmaceutical developments and the conduct of clinical trials.

Biotechnology Products – Recombinant Proteins

The activities under the recombinant proteins project include manufacturing of pre-commercial amounts of new therapeutic biological products with the appropriate support structures to foster Phase I and Phase II clinical trial activity and the establishment of three feeder nodes for process development for expression and purification of proteins to Australian researchers, along with subsidised access to contract manufacturing organisations for the manufacture of proteins for clinical trialling.

Manufacture of Human Cells for Transplant

This project provides access for researchers to facilities for the growth and supply of human cells for transplant under strict regulatory conditions. It supports the maintenance of Therapeutic Goods Administration (TGA) licensing for facilities in five States, together with subsidised access to these facilities for researchers to undertake the expansion and processing of human cells and tissue.

Population Health Research Network

The Population Health Research Network (PHRN) has been established to provide Australian researchers with access to linkable de-identified data from a diverse and rich range of health datasets, across jurisdictions and sectors. This will support nationally and internationally significant population based research that will improve health and enhance the delivery of health care services in Australia.

Australian Synchrotron

The Australian Synchrotron is an advanced third generation 3GeV light source with a high quality, low emittance, stable electron beam that generates synchrotron light of high brilliance, covering wavelengths from infrared to hard X-rays. The synchrotron currently has nine beamlines that allow high-throughput protein crystallography, spectroscopies based on a range of radiation types, diffraction and scattering techniques, and imaging and therapy.

Funding has been used to assist in the construction of the initial suite of beamlines at the Australian Synchrotron and to manage and deliver the International Synchrotron Access Program (ISAP). ISAP provides travel and subsistence support to Australian researchers to use overseas synchrotrons.

The Australian Synchrotron was also funded to construct the National Centre for Synchrotron Science: Outreach and Research Support Facilities. The facilities will include user accommodation, technical support and conference facilities at this 24 hour facility.

National Imaging Facility

The National Imaging Facility (NIF) is a national grid of imaging facilities to provide state-of-the-art imaging of animals, plants and materials. The NIF offers access to molecular-imaging instrumentation, advice and assistance for a range of Magnetic Resonance Imaging (MRI) and Positron Emission Tomography (PET) scanners and other live animal imaging equipment including bioluminescence, microCT, ultrasound and intravital microscopy.

Australian Microscopy and Microanalysis Research Facility

The Australian Microscopy and Microanalysis Research Facility (AMMRF) is an integrated national grid of microscopy and microanalysis instrumentation and expertise that supports a wide range of optical (i.e. light and laser), electron, X-ray and ion-beam microscopy techniques.

National Deuteration Facility

The National Deuteration Facility (NDF) operates multiple laboratories for the production, isolation and purification, and characterisation of deuterated biomolecules, as well as for the synthesis and characterisation of organic molecules.

Australian National Fabrication Facility

The Australian National Fabrication Facility (ANFF) has been established as a set of distributed nodes that provide researchers with state-of-the-art fabrication capability for nanoparticles, micro and nanostructures, nanosensors and nanotechnological devices.

Optical and Radio Astronomy

Through CSIRO, Astronomy Australia Limited and the Anglo-Australian Observatory, Australia is investing in the Australia Telescope National Facility, the Anglo-Australian Telescope and the Australian Square Kilometre Array Pathfinder (ASKAP) in Australia, as well as Australia’s participation in the Gemini Observatory and the Giant Magellan Telescope (GMT) in Chile.

Sustainable Energy: Biofuels

Two pilot-scale production facilities are under construction in Queensland and South Australia for the development and demonstration of biofuels production from lignocellulosic and microalgae biomass. These facilities aim to link innovations in product and process development with the assessment of commercial viability to enhance the uptake of these technologies in Australia.

Sustainable Energy: Fusion

The Australian Plasma Fusion Research Facility (APFRF) is a versatile plasma research facility, capable of accessing a wide range of plasma configurations or shapes, and utilising the associated state-of-the-art power and measurement systems that allow fundamental studies of plasma, the fourth state of matter. Future research using this facility is likely to include integrated modelling and data analysis, the physics of burning plasma, three dimensional effects on magnetic confinement and extreme materials for fusion reactors.

Heavy Ion Accelerators

The Heavy Ion Accelerators project is supporting the upgrade and enhancement of major university based ion accelerators facilities. The development of beamline detector instrumentation is an additional contributor to internationally competitive research.

Australian Biosecurity Intelligence Network

The Australian Biosecurity Intelligence Network (ABIN) aims to span human, animal, wildlife, plant and aquatic animal health and provide expertise, ease of communication and linked data for those involved in research, surveillance, preparedness and emergency responses.

Australian Animal Health Laboratory (AAHL)

The Australian Animal Health Laboratory (AAHL) features enhanced PC3 and PC4 facilities that are able to be used for work using genetically modified organisms in addition to working with dangerous infectious microorganisms.