Submission
2016 National Research Infrastructure Roadmap
Capability Issues Paper

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Executive Summary

Australian ecosystems: maximising the benefits (and minimising the risks) for the nation

Globally, the benefits from ecosystem services have been valued at $125 trillion per year (compared to a global GDP of $75 trillion).[1] Ecosystem services are arguably the most valuable component of the Australian economy as a whole, contributing at least as much and maybe more than manufacturing and service industries. But we can no longer take this wealth for granted. The coming decade – and the century to come - will be a time of unprecedented rate of change and challenges for Australia's diverse terrestrial ecosystems and the services they provide to our industries and communities.
How can we help our farmers, captains of industry and entrepreneurs navigate this uncharted territory? To ensure we maximise benefits, take advantage of new opportunities, and minimise risks to the nation, Australia needs nationally coordinated research infrastructure that enables ongoing ecosystem monitoring, increases scientific understanding of ecosystem processes, forecasts change and informs adaptation and mitigation options.

The foundations for much of this multidisciplinary integrated research infrastructure and synthesis capacity have already been built through previous NCRIS investment in TERN. The long-term ecosystem data streams this infrastructure is delivering are of similar fundamental importance in terms of benchmarking Australian ecosystem change as Cape Grim's observations are for benchmarking changes in the global atmosphere. As in the case of Cape Grim, Australia can't afford interruptions in the data streams - loss of these ecosystem benchmarks would mean we would be flying blind into the most disrupted decades humans have ever experienced.

The required capacity for national coordination across ecosystems, jurisdictions and scientific disciplines has also emerged through previous NCRIS investment in TERN. For example, this TERN Roadmap submission has been informed by an extensive stakeholder consultation process involving universities (ANU, UTas, UAdelaide, UQ, UWA, JCU, CDU, UniMelb, Monash, USyd, UWS, Macquarie, UniSA, Deakin), state government representatives (SA, NSW, Qld, WA, Tas), local governments, a range of NCRIS facilities (Atlas of Living Australia, Bioplatforms Australia, NeCTAR, the Australian National Data Service, Integrated Marine Observation System and the Biodiversity and Climate Change Virtual Laboratory), Australian government agencies (Department of Environment, Department of Agriculture and Fisheries and the Department of Innovation), other leading research

[1] R Costanza et al. (2011) Changes in the global value of ecosystem services. Global Environmental Change 26:152–158

agencies particularly CSIRO, consultants in the natural resource management sector, international partners with TERN (European Union, USA, UK, South Africa, Japan, China and Mexico) and others.

The thoughts of these people and institutions are represented in this document and have already changed practices within TERN – see Attachment 1.

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

The coming decade will be a time of unprecedented change for Australia's terrestrial ecosystems, and the industries and people that depend upon them. Our landscape is under threat from problems such as salinity, land degradation, serious degradation of water resources and loss of biodiversity, as well as from the often-negative impacts of pests, fire and climate change. To ensure we maximise ongoing benefits and minimise risks, nationally collaborative research infrastructure that enables interdisciplinary understanding of changing ecosystem processes is essential. In this context we welcome the Roadmap's identification of Environment and Natural Resource Management as one of the seven national Capability Focus Areas.

We note that at least four of the National Research Priorities are underpinned by Environment and Natural Resource Management infrastructure. We also note that Environment and Natural Resource Management research infrastructure is inherent in at least four other Capability Focus Areas (Health and Medical Science, Understanding Culture and Communities, Data for Research and Discoverability, Underpinning Research Infrastructure). In this context, specific provision for increased cross-capability collaboration would enable increased integration and leverage for investment in NCRIS, as well as allowing for truly novel outcomes by fostering unique collaborations.

Extending NCRIS investment to support Environment and Natural Resource Management would therefore strengthen almost all other NCRIS capabilities, and leverage investment in eResearch through reducing duplicative parallel investments from other Australian Government departments.

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

Features of optimal governance for national research infrastructure include impartiality inclusiveness, and being user-driven, with transparent decision-making processes that aim to deliver in the best interests of the nation. Capacity for agile responses to changing circumstances is also desirable. It would seem more effective and efficient for NCRIS to ensure that these characteristics are carried across capabilities in a similar manner.

Governance systems and performance metrics need to be designed appropriately for the nature of the infrastructure, to account for the differences in managing, for example, an instrument at one location compared with a network of nested initiatives at different locations across the continent. The proposed longer-term investments in NCRIS infrastructure (rather than the recent series of short-term funding cycles) will help improve efficiency of governance and will help NCRIS infrastructure to attract and maintain the best-skilled workers. Jobs will also be created because long-term surety of NCRIS funding will create incentives for staff education and training in innovative fields.

Inconsistent distinctions between 'infrastructure' and 'research' may be hampering our national capacity to address challenges. That is, national-need research infrastructure should include the

complete supply chain of infrastructure and information, including data collection, storage, integration and utilisation, and the workforce skills to implement all these components. National needs are also at risk of not being met if there is an inherent dependency on other sources of funding (e.g. ARC) to deliver on the 'research' outcomes of NCRIS investment in infrastructure. The value of the NCRIS investment will be greatly enhanced when all these components are supported and ultimately integrated to ensure national needs are being met.

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

Yes. International infrastructure, datasets and analyses can be leveraged to inform and help solve Australian problems and advance Australian science. These arrangements are often overwhelmingly to Australia's benefit, for example there are current agreements in place with a range of international space agencies, enabling Australian researchers to access international satellite infrastructure worth billions of dollars in foreign taxpayer investment. TERN then is able to cost-effectively provide the infrastructure for Australian researchers to contribute to the calibration and validation of satellite products and the development on new models through synthesis. This, in-turn, enables research innovation in the use and application of satellite data for the benefit of the nation. Critically, this infrastructure allows researchers to combine data from satellites, climate and TERN's various site and plot networks to support next-generation modelling and increased understanding of our ecosystems and land surface processes.

Reciprocity is vital if these arrangements are to continue, which means Australia must develop and maintain appropriate research infrastructure, people and networks to fulfil international commitments (e.g. CITES, DataONE, ground-based calibration data for NASA, JAXA and ESA satellite missions).

Thanks to previous NCRIS investment, TERN is considered "a world-leading example of building collaborative research infrastructure[2]" and as a result Australia is considered a global leader in terrestrial ecosystem observation. Continued coordinated international participation will be required if we are to maintain this lead and continue to enhance advantages through two-way participation in global scientific advances.

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

Instead of duplicating international effort, investments should be made in areas where Australia is world-leading, or involve solving Australian-specific problems. For example, no other nation will systematically invest in understanding or managing Australia's unique ecosystems or biodiversity; and Australian data streams are crucial for ensuring that global earth system models (often developed internationally) are useful for application to Australia. International access should only be prioritised where Australia cannot meet a fundamental need and should always include Australian research.

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

[2] Quote from Dr Michael Mirtl, Chair of both the International and European Long-Term Ecological Research Networks (his letter to Dr Alan Finkel is included in this submission as Attachment 2).

Yes. Strategic capacity-building to generate a pipeline of appropriately-skilled researchers is vital for the long-term use and sustainability of research infrastructure. In some cases (e.g. TERN) research infrastructure has not only built capacity but also catalysed the development of collaborative networks of appropriately-skilled researchers and technicians, and these networks in themselves should be considered another form of national research infrastructure. Loss of these networks and skill bases through decommissioning of infrastructure risks a reduction in Australia's capacity to innovate as skills and knowledge are lost. The build of NCRIS infrastructure has catalysed unique collaborations and fostered trust between organisations that were historically competitive. Rebuilding these networks in the future would be exponentially more difficult as the trust in such infrastructure programs would be severely diminished.

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

Encouragement of increased use of NCRIS research infrastructure by research institutions and incorporation of NCRIS facilities' data, knowledge and infrastructure into training of researchers and technical specialists would not only assist with training and skills development, it would also help generate the infrastructure workforce pipeline necessary to address Question 5. In addition, the management and synthesis of research infrastructure is an emerging field and as such, NCRIS has an opportunity to ensure that the social and intellectual capital developed through its significant investment is capitalised on in the future for national competitive advantage.

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

In general, Commonwealth-funded national research infrastructure should be open access, and its use should be encouraged by Commonwealth-funded research granting agencies such as the ARC. This applies particularly in the environmental space where such access provides benefits through the ongoing viability and sustainability of human habitation.

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

Institutions and people have invested and committed to NCRIS infrastructure in good faith in the expectation of long-term access and impact. This includes infrastructure that requires ongoing maintenance to avoid posing safety risks, and technical staff commitments that include severance liabilities. Should NCRIS funding discontinue, funding arrangements need to provide for the reasonable costs of decommissioning of NCRIS-funded infrastructure, to mitigate against the negative economic and social impacts from job losses. To minimise losses and reduce impacts, a 12-18 month time frame and appropriate budget should be provided to enable the closure/archiving/transitional arrangements for current capabilities.

Consideration needs to be given to the national impact and consequences of decommissioning. For example, there is scope to increasingly encourage NCRIS-funded capabilities to use NCRIS-funded high-performance computer and data centres (such as NCI and Pawsey Centre) for secure long-term data storage. Under current circumstances in the event of decommissioning there would be a high chance of data loss and fragmentation, with consequences for national and international research programs. This is an NCRIS-wide risk that needs to be urgently addressed with a view to securing the NCRIS legacy long-term.

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

To avoid reverting to hidden data, competing factional interests and in some cases, lethargy—public investment in national research infrastructure is a necessity. Some possibilities include: (a) provision and recommendations for other Commonwealth and State government departments to contribute to relevant NCRIS capabilities ("spreading the risk" for the Department of Education and Training); (b) in appropriate circumstances, consideration of provision for "selling" of NCRIS-generated data/products for commercial/industry use (currently free and open access); and (c) targeted industry investment in Australian research infrastructure as a form of carbon "offset".

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

In general, as early as feasible. Adoption of existing standards (where possible) or development of new benchmark standards is particularly relevant in terms of data collection and publication, and especially in the context of credible delivery to users.

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

Previous NCRIS investment in TERN has enabled Australia to become an internationally-recognised leader in terrestrial ecosystem observation infrastructure. In the words of Prof David Schimel (NASA JPL, USA) *"TERN is helping to bring about a paradigm shift in the way ecosystem science and management is done in Australia… The rest of the world is watching and hoping to learn."*, TERN infrastructure has enabled Australian researchers to lead international joint calibration and validation of recent NASA environmental satellite missions, using a novel approach in which satellite design, data delivery and development of the resultant carbon and water models occur together, in a fusion of international infrastructure capabilities.

Nonetheless we need to continue to learn from international models. For example, FLUXNET, an international network of regional greenhouse gas flux monitoring networks, has developed a valuable attribution system that enables tracking of data use and outcomes. Among other things, this enables demonstration of impact by showing (for example) that over a six-month period Australian data (the contribution of which to FLUXNET is partially NCRIS-supported through investment in TERN) have been used in over 100 international scientific projects.

The USA's Long Term Ecological Research Network is another infrastructure model worth consideration. This initiative has been maintained by the National Science Foundation (NSF) since 1980 and conducts ecological research programs that last decades and span huge geographical areas. This model contrasts distinctly to our current NCRIS model, which relies heavily on co-funding for operational delivery and linkages to ARC to enable the science application.

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

The National Ecological Observatory Network (NEON - a US analogue of TERN) is about to publish a book[3] about the lessons learned to date including some international examples of the consequences of decommissioning infrastructure. Additionally, Australia needs to weigh the costs of abandoning massive investment (e.g. Biodiversity fund) against the possible future benefits that could not be realised in such a short time program. Investment is rarely adequately monitored in terms of on-ground outcomes and as such, quantifying these benefits in traditional economic ways is fraught with difficulty. As such, thought should be given to building on previous investment rather than starting with new programs.

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

For research infrastructure, stable long-term investment is crucial. This not only enables the long-term data streams that are essential for understanding and managing ecosystems, it also improves sustainability because a steady pipeline of appropriately skilled personnel can be developed and maintained. For example, the National Science Foundation in the US funded their National Ecological Observatory Network (NEON - the equivalent of Australia's TERN) for thirty years in the first instance.

Better coordination and collaboration between NCRIS and other Australian Government science investment avenues (e.g. the ARC and NESP) would help encourage researcher use of, and hence additional support for, NCRIS' research infrastructure investment. The point of connection between TERN and the ARC and NESP is through our user consultation. TERN is focused on continuing its delivery of research infrastructure for the wider community and not be driven by factional needs.

Financing options which do not overly rely on multi-party in-kind and co-contributions are most appropriate. Capabilities established with multiple 'owners' lead to a split focus, are administratively burdensome, and have diluted productivity. The USA National Science Foundation funding of the USA's Long Term Ecological Research Network and the National Ecological Observatory Network are models worth investigating.

Health and Medical Sciences

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

There should be greater awareness that NCRIS capabilities in Health and Medical Sciences could leverage from relevant infrastructure that has already been developed by other NCRIS capabilities in Environment and Natural Resource Management. For example, greater collaboration and coordination between NCRIS capabilities (e.g. TERN, ALA, IMOS) could be beneficial to the Health capabilities in the areas of biologics/ biopharmaceuticals, 'omics, and biobanking. These benefits remain to be realised and must be supported by fundamental, ongoing investment to allow for innovation to succeed.

[3] Chabbi, A and Loescher H (eds) (in press) Terrestrial Ecosystem Research Infrastructures: Challenges, New Developments and Perspectives. CRC Press/ Taylor and Francis Group

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

Yes. Health areas of interest such as vectors, pathogens, and aerobiology could be supported by investment in a range of environmental monitoring infrastructure. If synergies can be found, harmonisation of data infrastructure between the Capability Focus Areas of Health and Environment would be desirable.

Environment and Natural Resource Management

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

We refer to Attachment 3, which contains excerpts from the 2006, 2008 and 2011 Strategic NCRIS Roadmaps with reference to terrestrial ecosystems. Despite incredible achievement in the past 10 years in developing and maintaining accurate continued monitoring of Australian ecosystem health for management and research, the statements on emerging directions and requirements for infrastructure capabilities are as relevant now as they were then.

The Issues Paper seeks to "strike a balance" between environment and development, and between environmental sustainability and economic growth. TERN believes that NCRIS's ambition for Australia should be greater: to maximise the co-benefits of Australian ecosystems for the well-being of people, the economy, land-based industries such as agriculture, and biodiversity.

Maximising the benefits to Australia from our terrestrial ecosystems over the coming decades will require sustained investment in collaborative research infrastructure that can detect ecosystem change and response, and inform adaptation and mitigation options. We concur that the identified emerging trend/demand for integration and synthesis – for example across remote sensing, multidisciplinary ecosystem observations and socio-biological data - requires establishment and long-term maintenance of a diversity of research infrastructure capabilities, and specific resourcing for strategic synthesis. The resultant whole-of-system thinking will enable interdisciplinary problem-solving to manage our emerging and increasingly complex future environmental risks.

The foundations for much of this essential integrated environmental research infrastructure and synthesis capacity have already been built through previous NCRIS investment in TERN. Examples of this long-term investment already bearing fruit include:

- enabling Australian researchers to take a leading role in the development of the international IUCN Red List of Ecosystems and enabling the Australian Government to be viewed as a leader in this emergent policy arena and to leverage from this work to meet environmental related reporting commitments
- helping Australia meet its Sustainable Development Goals through remote sensing and better estimating Australia's carbon and water fluxes at the continental scale
- providing data for the National Report on GHG Emissions and State of the Environment reporting
- enabling the Australian Government to more accurately report to the United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto, and measure progress

against emissions targets, by coordinating the establishment of Australia's Biomass Plot Library and directly collecting data for this
- the development of the North Australian Fire Information (NAFI) system, which uses remote sensing data to help manage fire (more here)
- better data to validate the operational CABLE/ACCESS climate models used by the Australian Government in designing its land-based carbon mitigation portfolio and in negotiations with the UNFCCC
- ensuring Australia has an influential role in two major international FAO programs, the Global Drylands Assessment and the Global Forest Survey (more here)
- sharing data with NASA which helps deliver precise information on the water and carbon exchanges everywhere on Earth's surface, vital for agriculture, land management and climate change forecasting (more here)
- Identification of the relative sensitivity of South Australia's six biodiversity hotspots to the impacts of climate change, under the first-ever systematic mapping of the State's plant biodiversity using a composite of TERN data and state herbarium records

While all of TERN's activities are relevant to this section of the Issues Paper, two areas are specifically mentioned as priorities:

- We concur that our current network of flux towers that monitor land-air CO_2 and water fluxes (currently delivered through TERN's OzFlux Facility) will need to be maintained and enhanced to provide the integrated climate and flux observations that Australia needs in the coming decades. Specifically, instrumentation infrastructure requires upgrading as technology improves and instruments age; and gaps in coverage of Australia's ecosystems need to be filled to improve representativeness. Data synthesis and modelling capabilities will help realise the greatest possible interdisciplinary benefit from these data streams and TERN has shown capability in these area.
- Remote sensing: investment via TERN already helps enable Australian access to international satellite-based remote sensing data. TERN's AusCover Facility already provides the calibration and validation data that underpins Australia's remote sensing products, as well as skilled personnel to develop algorithms and tools to fully exploit the data for the global satellite community. Sustained NCRIS investment in this area is essential if Australia is to continue taking advantage of this international infrastructure and investment. Provision for data synthesis and modelling will again be key to realising national benefits from these data.

We concur with the authors of the Issues Paper that sustainable use of Australia's natural resources (biodiversity, water, air, carbon, soil) is vital and that strategic investment in research infrastructure that enables more coordinated and collaborative research into sustainability in managed landscapes (i.e. production landscapes, urban and peri-urban landscapes) is an important next step.

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

NCRIS investment in TERN has enabled Australia to commence or increase collaborative activities with a large number of international research infrastructure initiatives, including UN-FAO, NASA, European Space Agency, NEON, Chinese Ecosystem Research Network, Japan Aerospace Exploration Agency, South African Ecosystem Observing Network, COOP+, GEOBON, GEOSS, ILTER, ANaEE, IUCN,

DataOne, US LTER and CZO. Sustained investment over the next ten years will enable Australia to realise significant benefits from these collaborations.

It is not possible to describe the tangible outcomes of all of these collaborations in detail here, but some indicative examples include:

- Australian input into a growing number of outputs and outcomes from NASA missions including ECOSTRESS which links terrestrial observations with International Space Station measurements to better understand future food production and ecosystem stability in Australia and across the globe
- Better insight into predicting vegetation growth (including crops), flood dynamics and regional weather forecasting for Australia through TERN's contributions to NASA's SMAP mission (global soil moisture forecasting)
- Calibration, validation and collaboration on observations to support the next generation of NASA's ecosustem models associated with the NASA OC02 Satellite Mission (http://www.nasa.gov/mission_pages/oco2/index.html).
- Australian leadership and influence in the development of an international system for evidence-based scientific assessments of the risk of ecosystem collapse (IUCN Red List of Ecosystems)
- Australian leadership of the international "Towards a Global Ecosystem Observatory" project which will be further scoped at the ILTER Open Science Meeting in South Africa in October 2016
- Australian input and influence into the United Nations System of Environmental Economic Accounting (SEEA) and the UN Sustainable Development Goals

Dedicated and reliable infrastructure investment in the form of people, ecosystem and biodiversity data, models, networks and equipment is needed to realise the full benefits of these international collaborations, and so that current capabilities can evolve into long-term ecological-economic research and long-term risk assessment networks. Owing to previous NCRIS investment in essential foundational capabilities such as TERN, ALA and IMOS, Australia is in a position to achieve a step-change in the efficiency and effectiveness of public investment in ecosystem knowledge.

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

Spatial gaps. We concur with the Issues Paper that there are gaps in our national coverage of Australian ecosystems, and note that these are wider than the three identified (arid, alpine, and tropical). During a decade that will experience unprecedented rates of environmental change, Australia needs to ensure infrastructure is in place to baseline its current ecosystems (including managed/production landscapes) and detect how they are changing over space and time. This information will be essential if Australia is to maintain current levels of agricultural and economic productivity, maximise conservation of biodiversity and minimise impacts on social well-being. TERN's existing multidisciplinary research infrastructure is well-placed to address this issue by providing representative baselines and ongoing detection of ecosystem changes at nested scales.

For example, despite the existence of spatial gaps, TERN's multidisciplinary, scalable approach has already enabled the most complete synthesis of environmental change in Australia to be captured in a single data-rich product[4] that demonstrates the value of existing long-term ecological research in Australia for monitoring environmental change and biodiversity. In another example, TERN's expertise and data enabled detailed risk assessments for a diverse selection of Australian ecosystems from the coast to the central deserts, the tropics to the temperate regions and from the mountains to the sea.

Australia's 5.9 million km^2 Antarctic Territory is of significant size and of increasing strategic importance to our nation. Its terrestrial ecosystems, and how they are changing over time, represent a sizeable gap – and opportunity - in Australia's current and future environment and natural resource management capability.

Specific Capability Gaps. NCRIS' investment in TERN to date has successfully delivered many, but not all, of the terrestrial ecosystem research infrastructure capabilities required. As examples, Australia has an urgent need, but not the current capability, to monitor terrestrial fauna accurately and efficiently across representative ecosystems (with some exceptions); we have insufficient capacity to monitor change in managed, production, urban or peri-urban landscapes; and we know there is a need for research infrastructure that supports effective and evidence-based ecological restoration efforts (an increasingly important gap as the rate of environmental change and intervention investment accelerates in the coming decade). In addition, a strong focus on infrastructure to support more effective monitoring and evaluation of research and management effort is needed and this would help increase the impact of NCRIS' investment in this Capability Focus Area over time.

Network Capability Gaps. We have long recognised that skilled people and their networks are as important as tangible infrastructure for TERN and Australian science and prosperity. A greater emphasis on fostering skills and networks within and across NCRIS capabilities would help increase the value of the Australian Government's investment.

Greater focus on how this Capability can improve socio-economic outcomes. There is considerable unrecognised scope within the Environment and Natural Resource Management capability focus area for the creation of jobs and economic growth. Apart from economic benefits arising from increasingly sustainable management, there are many examples of newly-developed data infrastructure driving new job creation (e.g. *iTracker* and *VegNet*). Uncertainty about the future of NCRIS has contributed to the loss of Australian STEM jobs in recent years, and we hope that the Roadmap process will restore confidence and reverse this trend, for the benefit of the nation.

Underpinning Research Infrastructure

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

Long-tail and interdisciplinary research need to be supported by Underpinning Research Infrastructure. Capabilities identified in "Data for Research and Discoverability" should be leveraged

[2] Lindenmayer D, Burns E, Thurgate N & Lowe A (eds) (2014) Biodiversity and Environmental Change: Monitoring, Challenges and Direction. CSIRO Publishing, Melbourne, Australia, 2014, xiv + 624 pp

to make the data that are used and generated in the high-performance computing environments accessible and discoverable. If, for example, AARNET was made available to NCRIS partners outside of universities and CSIRO, this would help with easier access, movement and storage of large datasets.

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

There are a number of international programs we can engage in, and learn from, including:

- InCommon - https://www.incommon.org/
- OpenAire - https://www.openaire.eu/
- EuDAT - https://www.eudat.eu/
- XSEDE - https://www.xsede.org

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

Robust access and authentication services are required, which will work for all the services available in eResearch infrastructure including non-web based services. This would enable machine-to-machine access to data and services provided by different agencies. If state and Australian government agencies could federate access, this would substantially improve research collaboration between research communities and policy makers.

Data for Research and Discoverability

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

Vast amounts of data are being generated across NCRIS, yet there are currently no secure long-term storage options available that also permit ready access for the wider research community. This problem needs to be urgently addressed to protect the existing investment in NCRIS and preserve its legacy. NCI, NeCTAR and RDS have offered computing and storage infrastructure to the previous NCRIS program but in order for this to evolve into reliable, integrated and trusted infrastructure, the longevity and certainty of services need to be guaranteed. In addition to the points outlined in the Issues Paper, we recommend that in the future the infrastructure should be more flexible and scalable to meet the needs of the infrastructure user community. Current cloud infrastructure is also implemented by state-based eResearch centres, and in future it would be worth NCRIS considering how best to coordinate to achieve a truly national and integrated approach with similar service offerings, infrastructure governance and seamless access to services and data hosted at different cloud nodes.

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

Yes, international opportunities of advantage to Australia include:

- Taking up the invitation for Australia to join the European Space Agency http://www.esa.int/ESA as an Associate Member

- EuDAT- https://www.eudat.eu/
- Horizon 2020 - https://ec.europa.eu/programmes/horizon2020/
- Helix Nebula - http://www.helix-nebula.eu/
- Apache Airavata - https://airavata.apache.org/
- European Open Science Cloud - http://ec.europa.eu/research/openscience/index.cfm?pg=open-science-cloud

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

Re-examination of the current governance and operating structure of the existing NCRIS cloud infrastructure is warranted. A truly integrated service would enable each of the infrastructures to work closely to deliver serious impact at a global level. Currently, NCRIS data infrastructures perform domain-specific data management practice but use infrastructures provided by NCI, NeCTAR, ANDS and RDS. In future, the infrastructure should offer to value-add to already-built capabilities from domain-specific NCRIS projects. Easy access of cloud infrastructure to international collaborators will significantly improve collaboration and accessibility of Australian science.

Other points include:

- To become a reliable and robust infrastructure, the providers should offer clear user-friendly services that include overall, consistent data governance policies at the cloud infrastructure level.
- Policy and infrastructure should support the archiving and preservation of all research datasets, including sensitive and confidential datasets, from across all domains.
- Cloud and high performance computing should be closely linked and complement each other, rather than be considered competing technology. The cloud infrastructure should be structured in a way that encourages researchers from across disciplines to leverage the cloud capabilities, while also making high performance computing (HPC) resources more accessible from cloud platforms.
- Moving ahead, infrastructure should provide capability to build innovative tools to enable high impact digital science. These include easily accessible and usable tools to transfer data, upload data, migrate data, replication services, high availability data services, and environments to enable reproducible science.

Other comments

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

One of the challenges in any infrastructure development is achieving uptake. NCRIS leaders should view the need for increased uptake as a top priority, and thereby seek to ensure there are whole-of-NCRIS training initiatives to foster opportunities within the research community to better use the infrastructure capabilities. A whole-of-NCRIS level program will provide opportunities to improve coordination, enable cross-pollination of ideas and lead to innovative applications from the use of the infrastructure.

ATTACHMENT 1: TERN's strategic framework at: http://tern.org.au/Plans-Reports-pg29540.html#Strategic Framework

ATTACHMENT 2: international collaborations

International Long-Term Ecological Research Network
European Long-Term Ecosystem Research Network
Chair-Person: Michael Mirtl
Email: Michael.mirtl@umweltbundesamt.at

http://www.ilternet.edu
www.lter-europe.net

ILTER Office
LTER-Europe Office

To the Australian National Collaborative Research Infrastructure Strategy Expert Working Group
Department of Education and Training
Dr. Alan Finkel, AO
Australia

Subject: Letter of Support for TERN

Dear Panel and Dr. Finkel,
September 5, 2016

The Australian Terrestrial Ecosystem Research Network (TERN) network, co-ordinated by the central office at the University of Queensland, has been part of the core networks that initiated both the International Long-term Ecosystem Research Network (ILTER) and its important East Asian Pacific regional group (EAP). The scientists and representatives of LTER Australia have been highly active at their sites and attended all major international meetings. TERN hosted the annual international ILTER conference in 2009 back to back with the 10th INTECOL Congress/Ecological Society of Australia meeting in Brisbane.

One of the key characteristics of TERN and the TERN team is, that they have been striving for innovative solutions many other countries and continents could only dream of. In face of the current challenges of environmental and ecosystem research this concerns mainly integrative approaches, where core components of this research and monitoring are integrated to jointly explore cause-effect relationships, mitigation and adaptation options. The modular design conceptualised and implemented by TERN, comprising – inter alia – larger scale and representative monitoring (abiotic, biotic), indicator research sites/transects for biodiversity and highly instrumented sites under one umbrella, which provides the platform for data integration and analyses has been recognised and multiply presented as cutting edge example around the globe.

- -TERN is an essential part of the growing international ecosystem observatory community
- -TERN helps provide essential services to the international community e.g. website support for ILTER
- -TERN provides a world leading example of building collaborative research infrastructure
- -TERN helps provide Australia access to important international programs, data streams and research network
- -TERN infrastructure is helping provide data to global projects which are creating innovations in science

- -TERN helps secure international relationships vital to future innovations at a global scale

Specifically, the European Environmental Research Infrastructures development process and strategy have been using TERN as a blueprint, which is well reflected in participations of TERN to numerous scientific advisory boards of individual research infrastructures and research infrastructure integration processes. What Australia and TERN have achieved in the field of research, remains the vision for European integrated research infrastructure. We cannot sufficiently value the successful efforts to associate diverse infrastructure components and research groups and to manage joint operation for the sake of what no component can achieve individually.

From a global and European ecosystem research perspective anything relse than an intensified continuation of TERN as an infrastructure and exemplary integration process would be a fatal signal and depriove leading research infrastructure development processes of a triggering flagship example.

With this we want to congratulate Australia once more for the globally visible achievement TERN represents and wish the country as well as the global ecosystem research a successful continuation.

Yours Sincerely
Dr. Michael Mirtl
(Chairman of ILTER and LTER-Europe)

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ILTER Office
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To the Australian National Collaborative Research Infrastructure Strategy Expert Working Group
Department of Education and Training
Dr. Alan Finkel, AO
Australia

Subject: Letter of Support for TERN

September 5, 2016

Dear Panel and Dr. Finkel,

The Australian Terrestrial Ecosystem Research Network (TERN) network, co-ordinated by the central office at the University of Queensland, has been part of the core networks that initiated both the International Long-term Ecosystem Research Network (ILTER) and it´s important East Asian Pacific regional group (EAP). The scientists and representatives of LTER Australia have been highly active at their sites and attended all major international meetings. TERN hosted the annual international ILTER conference in 2009 back to back with the 10th INTECOL Congress/Ecological Society of Australia meeting in Brisbane.

One of the key characteristics of TERN and the TERN team is, that they have been striving for innovative solutions many other countries and continents could only dream of. In face of the current challenges of environmental and ecosystem research this concerns mainly integrative approaches, where core components of this research and monitoring are integrated to jointly explore cause-effect relationships, mitigation and adaptation options. The modular design conceptualized and implemented by TERN, comprising – inter alia - larger scale and representative monitoring (abiotic, biotic), indicator research sites/transects for biodiversity and highly instrumented sites under one umbrella, which provides the platform for data integration and analyses has been recognized and multiply presented as cutting edge example around the globe.

- TERN is an essential part of the growing international ecosystem observatory community
- TERN helps provide essential services to the international community e.g. website support for ILTER
- TERN provides a world leading example of building collaborative research infrastructure
- TERN helps provide Australia access to important international programs, data streams and research network
- TERN infrastructure is helping provide data to global projects which are creating innovations in science
- TERN helps secure international relationships vital to future innovations at a global scale

Specifically, the European Environmental Research Infrastructures development process and strategy have been using TERN as a blueprint, which is well reflected in participations of TERN to numerous scientific advisory boards of individual research infrastructures and research infrastructure integration processes. What Australia and TERN have achieved in the field of research, remains the vision for a European integrated research infrastructure. We cannot sufficiently value the successful efforts to associate diverse infrastructure components and research groups and to manage joint operation for the sake of what no component can achieve individually.

From a global and European ecosystem research perspective anything else than a intensified continuation of TERN as an infrastructure and exemplary integration process would be a fatal signal and deprive leading research infrastructure development processes of a triggering flagship example.

With this we want to congratulate Australia once more for the globally visible achievement TERN represents and wish the country as well as the global ecosystem research a successful continuation.

Yours sincerely

Dr. Michael Mirtl
(Chairman of ILTER and LTER-Europe)

Attachment 3: Excerpts from previous NCRIS infrastructure roadmaps

*Below are excerpts from previous Commonwealth infrastructure roadmaps outlining the rationale for investment in **terrestrial ecosystem research infrastructure.** These statements remain as relevant today as when they were written.*

National Collaborative Research Infrastructure Strategy Strategic Roadmap (2006) Commonwealth of Australia:

Rationale for terrestrial ecosystems investment:

"Soil and water are fundamental to the wealth we generate from our lands, while our unique biodiversity is adapted to our variable climatic patterns and holds the key to sustainable living on our continent. Our landscape is under threat from problems such as salinity, land degradation, serious degradation of water resources and loss of biodiversity, as well as from the often-negative impacts of pests, fire and climate change…

- Landscapes are made up of multiple, complex, interrelated systems, which need to be understood and managed in an integrated way.
- …significant investment is being made in collecting and enhancing the integration of terrestrial ecosystem data…much remains to be done.
- ...strong support for action to improve the quality and level of collection and integration of data relating to Australia's terrestrial ecosystems.
- …need for this action to take place within a framework that is cognisant not only of interrelationships within the terrestrial environment, but also of interrelationships between the terrestrial environment and the coastal, marine and atmospheric environments.
- …recognition of the magnitude of the task – not only intellectually (given the complexity of the systems being studied) but also organisationally and politically (given the number of jurisdictions and agencies involved and the number of initiatives that are underway)."

Specific requirements:

"…that support be provided for stakeholders to further scope issues and options related to this capability during 2006, leading to the development of a full investment proposal through facilitation commencing later in 2006 or 2007."

Strategic Roadmap for Australian Research Infrastructure (2008) Commonwealth of Australia:

Rationale for terrestrial ecosystem investment:

"A better understanding of environmental systems, and the effects of population growth and climate change on these systems, is essential to our ability to mitigate, respond and adapt to these changes and ensure the ongoing viability and sustainability of human habitation.

…knowledge of the Australian continent is central to understanding how the natural environment evolved, locating the minerals and energy resources it supplies, and anticipating and responding to the natural hazards it creates."

Specific requirements:

"Detailed holistic studies are necessary for understanding the environmental systems and the earth, requiring multidisciplinary approaches and infrastructure to support the:

- Comprehensive, coordinated measurement and monitoring of environmental components and earth properties over the long term;
- Management of data acquired to ensure that all data collected is organised, retained, accessible and linked in a way that supports a variety of research activities; and
- Analysis and modelling that helps integrate and synthesise data, and enables the improved understanding of how these systems function and change.

…An ongoing and significant challenge is the implementation and maintenance of a long-lived site and observing network that supports research and management at a range of scales from regional to continental. Detailed site observations can be used to calibrate and inform regional and continent-wide investigations, and observations made at regional scales allow the context for site investigations to be established.

Further investment is likely to be needed in:

- Expanded data management services to support discovery, access and interoperability of datasets, and national coordination in areas such as developing metadata standards; Tools for linking and analysing datasets, for input to models and determining where data gaps exist; Provision of enhanced fit-for-purpose models and predictive capabilities; and
- Further development of a priority network of baseline sites, 'super sites' and long term ecological research sites, with agreed measurement protocols, sensor technologies and networks for improved and coherent measurement of parameters in priority ecosystems."

Strategic Roadmap for Australian Research Infrastructure (2011) Commonwealth of Australia:

Rationale for terrestrial ecosystems investment:

"Investment in research infrastructure capability for terrestrial systems requires an integrated and interdisciplinary view due to the complex and inter-related nature of the systems themselves. A collaborative and integrated research capability is required with observation and surveillance infrastructure coupled with data-intensive analytical techniques. More specifically, the research infrastructure capability should provide a foundation for research into how ecosystems are structured and function, the role they play in providing resources and how they can be managed sustainably."

Specific requirements:

Investments to date represent a good start in establishing the necessary long-term observing and information systems for terrestrial systems research. While maintaining and strengthening existing capacity, there is a need to extend the coverage across a range of ecosystems and to improve integration.

Key infrastructure needs include:

- extension of the network of baseline sites, 'super sites' and long-term ecological research sites to include aquatic ecosystems, the coastal zone and managed landscapes, with agreed measurement protocols
- observing systems to monitor soil condition to enable research into soil carbon sequestration as well as spatial distribution of soils and changes over time, including water storage, carbon dynamics and nutrient availability
- standardisation of methods for measurement and analysis (for example those relating to the carbon cycle)
- improved capacity for measurement and monitoring of freshwater ecosystems and biodiversity with increased focus on the function, resilience and response of aquatic ecosystems, including experimental research infrastructure at the ecosystem scale
- provision of enhanced fit-for-purpose models and predictive capabilities
- sensor technologies and networks for improved and coherent measurement of parameters in priority ecosystems
- support for the emerging techniques of environmental metagenomics
- shared approaches to data management and ICT infrastructure to support discovery,
- access and interoperability of datasets, and national coordination in areas such as developing metadata standards