Submission
2016 National Research Infrastructure Roadmap
Capability Issues Paper

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1 Introduction

Australia's Academic and Research Network Pty Ltd (AARNet) operates Australia's National Research and Education Network (NREN). The AARNet network is a critical national asset that is fundamental to enabling Australian researchers to leverage investments in all other institutional, national and international e-Infrastructure. AARNet provides extremely high-speed, extremely high-quality broadband between instruments, facilities, campuses and institutions using dedicated national and international digital infrastructure, that interconnects the Australian research sector through the global NREN community to the global research sector.

AARNet supports its ongoing operations and technical upgrades through membership subscriptions and fees, and hence is not dependent on ongoing or operational funding through NCRIS or any other national source. Expansion of the network, however, requires capital investment from member institutions or the Commonwealth (either directly, or via funds provided to members).

In this submission, a number of research infrastructure capability gaps are identified as summarised below and further detailed in the remainder of the response.

2 Executive Summary

2.1 Network (Data Access and Movement) Capability Gaps

Connecting the Unconnected – A number of facilities, instruments, campuses and regions are not currently connected to the AARNet network, which hampers access, increases operational costs, and reduces the research impact of facilities and instruments. Lack of access to AARNet also reduces the effectiveness of research and researchers in regional and remote Australia (Question 30).

Asian Connectivity Parity – Compared to the currently adequate capacity of research broadband capacity between Australia and the US, and hence onward to Europe, the available capacity to Asia is a bottleneck. This does not reflect the increasing importance of collaboration with the Asian research community and industry to Australia (Question 30).

National Network Backbone Robustness – Although constructed with high levels of redundancy, AARNet's backbone network has some non-redundant paths that need to be duplicated for research continuity (Question 30).

Improved Connectivity to Data and Services – Many large data sets, digital services and resources, and also industry/government collaborators, happen to be hosted at organisations that are not physically connected to, or members of, AARNet. As a result, these data sets and collaborators, cannot be readily integrated into the research workflows, facilities and capabilities normally available to the AARNet-connected research community (Question 30).

End to End Data Movement – The boundary between AARNet and the campus infrastructure of connected institutions is a critical component and potential chokepoint for data access and transfer between institutional and national research infrastructure (Question 30).

2.2 Other Capability Gaps

National Internet of Things (IoT) Sensor network – Without displacing ongoing research into sensors networks, such a capability would facilitate and accelerate research into the applications of IoT by providing an open platform accessible to not only researchers, but industry and the general public (Question 18).

National "CyberRange" - Cyber-security research requires testbed and experimentation facilities (a "CyberRange") where research, training and industry collaboration can be conducted in a secure and constrained environment (Question 27).

Authorisation Services – Although authentication services ("who are you") are provided by the Australian Access Foundation (AAF), authorisation services ("what are you allowed to access/do") are also required to support increasingly complex research workflows (Question 30).

2.3 Comments on Identified Capabilities

Research Data Management – Consistent with the objectives of the Australian Research Data Services (ARDS) element of the eResearch Framework paper, an integrated national approach to providing access to all data that can be of use to Australia's research sector, regardless of its location – whether within an institution, a national facility, government agency or industry – is required. The provision of the underlying storage at national and institutional level is somewhat independent of this requirement (Question 33).

National Digitisation Capability – Digital connectivity between universities, digital repositories, cultural and collecting institutions and entities that provide digitisation services, is critical to enabling this capability (Question 30).

CAPABILITY GAP	REQUIREMENT	RESEARCH IMPACT	NATIONAL PRIORITY	PRIORITY
CONNECTING THE UNCONNECTED	Extend network capacity into regional Australia.	Enable partnerships and access parity.	Regional Development	1
ASIAN CONNECTIVITY PARITY	Strengthen and expand network capacity into Asia.	Enable research collaboration and access parity.	International Collaboration	2
NATIONAL NETWORK BACKBONE ROBUSTNESS	Strengthen and expand network capacity within Australia.	Meet increasing demand and dependency on infrastructure.	Productivity, Regional Development	3
IMPROVED CONNECTIVITY TO DATA AND SERVICES	Extend network capacity into public sector and industry.	Enable data access and transfer capacity in service of research.	Industry Partnership	2
END TO END DATA MOVEMENT	Prioritise efficiencies and capacity at critical network linkage points.	Enable data access and transfer capacity with greater efficiency.	Productivity	1
RESEARCH DATA MANAGEMENT	Efficient access to data storage or archives.	Enable data access and transfer capacity regardless of location.	Productivity	1
NATIONAL INTERNET OF THINGS SENSOR NETWORK	Use research enabling effort to build the infrastructure.	Focus research time on exploiting this capability.	Innovation	2
NATIONAL CYBERRANGE	Use research enabling effort to build the infrastructure.	Focus research time on exploiting this capability.	Innovation, Industry Engagement	2
AUTHORISATION SERVICES	Enhance permission mechanisms to meet service and data access needs.	Enable data access and transfer capacity securely.	National Security	2
NATIONAL DIGITISATION CAPABILITY	Use network capacity and research enabling effort to build the infrastructure.	Focus research time on exploiting this capability.	Productivity	2

Table 1. Capability Gap Summary

This table documents the research requirements leading to the capability gaps AARNet has identified in this response. The research impact and relative priority as assessed by AARNet (1 being the highest priority); and a simple analysis of how the capability gap impacts National Priorities is also provided.

Capability Gap	Health and Medical Science	Environment and National Resource Management	Advanced Physics, Chemistry, Mathematics and Materials	Understanding cultures and Communities	National Security	Underpinning Research Infrastructure	Data for Research and Discoverability
Connecting the Unconnected		✓	✓			✓	
Asian Connectivity Parity			✓			✓	
National Network Backbone Robustness						✓	
Improved Connectivity to Data and Services	✓	✓		✓	✓	✓	✓
End to End Data Movement	✓			✓		✓	
Research Data Management	✓			✓			✓
National Internet of Things		✓					
National CyberRange					✓		
Authorisation Services						✓	
National Digitisation Capability				✓		✓	

Table 2. Mapping between capability gaps and focus areas

This table summarises the cross-references between the capability gaps identified by AARNet and the capability focus areas, as documented in the response.

3 National Research Infrastructure Policy Issues

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

Broadly, AARNet believes these capability areas are appropriate, but note that the "Understanding Cultures and Communities" capability area represents a significant proportion of the university based research system and hence have a very diverse range of requirements. This is expanded upon in the response to question 26.

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

Models of governance that foster and facilitate long-term co-investment from institutions, and potentially research disciplines are in AARNet's experience extremely desirable. More specifically:

- They are the basis for more sustainable, more collaborative national research capabilities
- When properly constructed, they allow both large and small contributions to be made by large and small institutions, towards a national capability
- They force institutions to have "skin in the game", and in return (again, if properly constructed) provide a research impact return consonant with the co-investment.

As a case study, AARNet's model is described in the response to Question 10.

More specifically, the "frameworks for accountability" characteristic needs to encompass some of the other characteristics listed in Question 2, including "access models", "level of interoperability" and "collaboration and networking", as well as robust business and financial planning, change management, and evaluation.

These two measures will "guide future investment by ensuring a coordinated approach across Government and key stakeholders" (S2.1) and to undertake "strategic investment decisions" (S2.2). The stakeholder environment for NCRIS funding (in particular) is a complex mix of universities, government agencies, private research institutes, state, national, and international partnerships. Making co-investment, planning, change management and evaluation an explicit part of the frameworks for accountability signals clearly that efforts are to be applied to optimal coordination of business and financial planning (across different budget and financial reporting cycles) and review, human resource management (skilled staff retention), and change management (for set up or shut down of any funded initiatives).

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

Research is increasingly collaborative and global. For Australian researchers to remain competitive, they must have access to world class facilities regardless of their location. It is entirely appropriate for investments in the national interest to be made

in international research infrastructure in all the dimensions identified in the discussion paper.

The digital connectivity provided by AARNet's international connectivity, and peering with the globally interconnected NREN community is critical to enable this.

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

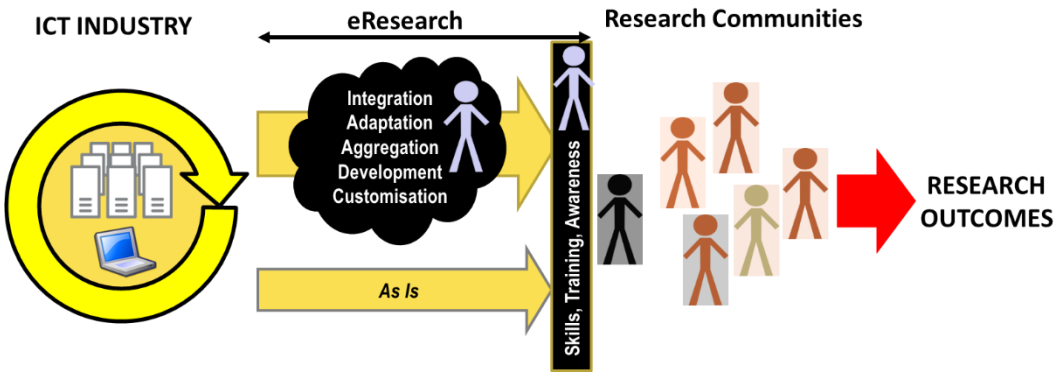
The relative merits of securing access to a national facility compared with developing a facility in Australia should be informed by how each approach differentiates the research quality and research impact of the particular discipline or disciplines that might use the facility. The quality and impact measures will be determined by the unique attributes and nature of each discipline, implying that the conditions and scenarios for each facility decision will need to be assessed separately. Indeed, non-technical factors will play a role in the assessment for prioritising access to national or international facilities, and, determine who "owns" and "manages" any connections and use of international facilities.

Many facilities and instruments produce digital output, and the volume of data produced is rapidly increasing. The digital connectivity provided by AARNet's international connectivity and peering with the globally interconnected NREN community is critical to ensuring such facilities and instruments are readily accessible to Australian researchers, and in instances where such instruments are located in Australia, to international collaborators.

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

Skills and awareness are critical to extracting the maximum value from any research infrastructure investment, particularly within the Information and Communications Technology (ICT) domain that AARNet operates within.

As illustrated in the graphic below, the ICT industry evolves new technologies, capabilities and consumption models extremely rapidly, faster in many cases than some researchers and institutions are able to leverage to improve research outcomes. In some cases, new capabilities can (and are) taken up "as is" (eg. Excel, smart phone), and in other cases the capability needs to be developed, integrated, adapted, customised, or scaled up to meet the needs to the research communities (eg. supercomputers, NRENs, application software).



In either case, the research workforce needs to include technicians to provide the adaption, integration, etc. functions, and "business" analysts (with research sector and research domain knowledge) to engage with the research community to provide training, support and awareness. The expert staff (technicians and analysts) that support the infrastructure in this space between the ICT industry and the research community, make up what is often described as "eResearch". eResearch skills are needed to translate access to and the value of national research infrastructure, including support for research data management and informatics which aids in the digital transformation of research.

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

National research infrastructure facilities are natural concentration points for technical expertise (eg. AARNet, AAF, ANDS) and hence form part of the research infrastructure. Such facilities can (and do) also form a hub from which eResearch analysts can provide outreach to research communities and researchers, both directly, and through institutions. In some cases, it may only be at the national level of infrastructure investment that it will be possible to attract and retain technical (rather than academic) expertise and personnel that help to differentiate Australia's research effort.

National research infrastructure can also significantly assist the development of research training and skills by presenting a single, simple, stratified view of the capabilities being funded and developed. By contrast, if no stratified view is presented, researchers and research support staff must be prepared to deal with different tools, terminologies, assumptions and methods for every research discipline or even collaboration that they encounter, as they will all have had to haphazardly collate their own eResearch ecosystem.

More generally, it's also important to promote the importance and value of technical professional staff responsible for operating national facilities, by providing pathways for technical staff to move both between institutions, to/from national facilities and programs, and industry as appropriate. This can be achieved by advocating for stronger professional career paths, through approaches that might include more uniform professional grades across institutions, better alignment of grades to industry-relevant skills and programs of ongoing professional development across the sector.

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

Institutions play a fundamental, long-lived and crucial role in providing careers for the researchers, and it's clearly in their interest to attract, develop and retain the highest quality staff (driven by rankings, and ERA as simplistic examples).

Institutions are also critically important in the development of all research infrastructure, particularly and specifically with regard to ensuring that their research communities are aware of, and have the necessary skills to take advantage of national research infrastructure resources. A very basic mechanism for fostering this linkage is to provide incentives for universities to co-invest (in addition to any in-kind) in national research infrastructure funding arrangements.

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

The process of merit allocation of research infrastructure resources (eg. supercomputer cycles, telescope observing time, access to manuscripts) is entirely appropriate to ensure Australia's research remains globally competitive, and to maximise the research output from costly, scarce, finite and possibly unique facilities or instruments.

Conversely, merit allocation is not appropriate for "consumable" resources for which there is not a "market failure", eg. general purpose digital storage is available in many forms through a range of consumption models, and AARNet acts as a demand aggregator for networking services. Of course, there are likely to be instances where "consumable" infrastructure does not provide the attributes required to support the specific needs of some researchers, and some level of bespoke adaption may be required (also address in the response to Question 5).

Given the diverse and complex mix of emerging and mature, peak and long tail, research requirements, the capabilities and solutions need to be efficient and fit for purpose. This principle is applied by AARNet to provide extremely large capacity services to peak facilities, as well as more basic connectivity.

Another principle that would have material research impact would be to remove funding and jurisdiction barriers that impede the establishment of research collaborations. Other parties that are important agents in enabling data collection or access, community engagement, or research, need to be able to provide their assets, facilities, and services, to support research. Examples include the National Library of Australia and the Australian Bureau of Statistics (custodians of nationally significant cultural and social data that supports research), Aboriginal and Torres Strait Island councils (conduit for community engagement in health, education, welfare etc), Mission Australia (a non-profit that conducts social research), and Grey Innovation (suppliers of research equipment for Sense-T). Removing barriers may involve extending the national research infrastructure to enable public sector agencies, regional communities, non-profit organisations, and industry partners to be

connected into and operational within the community that use the "assets, facilities and services to support research". That is a community comprised of agents that: conduct research (universities and institutes), are associated with research (industry and non-profits), enable research (data custodians), and are impacted by research (industry and community).

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

Co-investment by relevant stakeholders (institutions, disciplines) is key to ensuring a facility has a renewal, refresh or migration path for the capabilities and/or services it provides. Such a facility should be accountable to these stakeholders not only via an on-going co-investment model strategy, but also through participative governance arrangements.

This is an explicit and fundamental characteristic of the AARNet Model detailed in the response to Question 10.

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

AARNet has operated for nearly three decades, and is perhaps a useful financing and participative governance model to consider. The key features of the AARNet model are described below.

Structure and Governance

AARNet is owned and operated by AARNet Pty Ltd, a not for profit company owned by Australian universities and CSIRO. The AARNet Board includes three university vice chancellors, a CSIRO nominee, four independent directors, the AARNet CEO and three university CIO's. This structure ensures a level of independence from any one institutions, allowing AARNet Pty Ltd to operate as a national capability (or "facility") in the best interests of all shareholders. Consequently, AARNet regularly makes very long term (10+ year) investments in the interests of the research and education sector as a whole, which would be impractical for any individual institution to make.

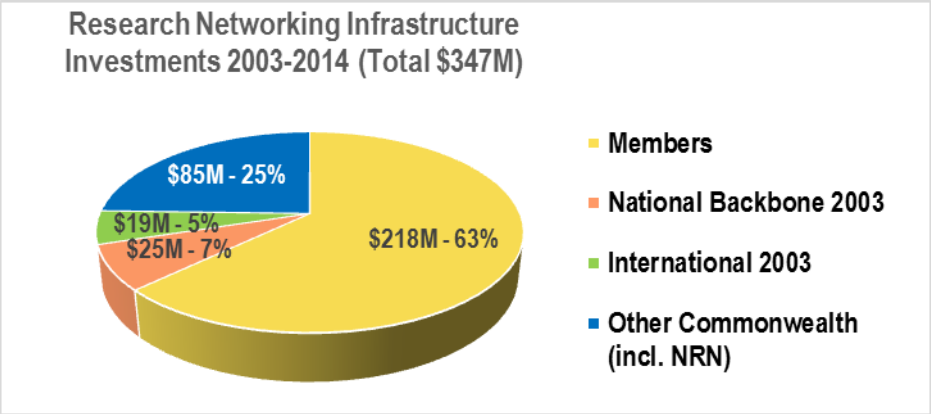
Subscription/Consumption Model

AARNet is funded through member subscriptions determined by a formula based on an organisation's staff and student numbers, and research income. This annual fee is aligned to financial systems/budgeting of education institutions and includes only a very small component that is usage (volume) based. Subscription fees are paid by the institution but the benefits flow directly to individual researchers (unless an institution elects to undertake internal cost recovery).

Co-Investment

Because of the Subscription model, there has been consistent and extensive co-investment from shareholders and members, with the Commonwealth, over many

years. This has proven to be a particularly powerful mechanism to allow large and small institutions to contribute to and benefit from a national capability.



Wholesale model

AARNet provides national and international services to and between institutions and campuses which are reticulated to researchers and academics through institutional campus networks. Every institution therefore participates in an active partnership to provide an end-to-end service to researchers. Similarly, most of AARNet's layered services (eg. eduroam, CloudStor storage) are supported with the active involvement of intermediaries (institutions and disciplines).

Demand Aggregation

AARNet aggregates the (data) telecommunications needs of:

- All Australian universities, across all of their business functions (Education, Research, Administration),
- All other research organisations,
- Other organisations with a teaching or training mission,
- Galleries, Libraries, Archives and Museums,
- Organisations that support/service education and research,
- Other countries (eg. NZ) and institutions (eg. University of South Pacific) in the region.

Through simple economies of scale, this reduces the unit cost of services for shareholders and members.

Operating Surplus

A modest operating surplus ensures there is a reserve that is used to refresh and upgrade active equipment as it ages, and can also be used to take advantage of time-critical commercial opportunities, eg. international under-sea fibre projects.

Internationally Aligned and Integrated

AARNet is directly connected to, and integrated with, all other NRENs in the world. This NREN community supports the global research community through the free (no-

cost) exchange of research traffic and the development of unique capabilities to meet the demands of the global research community. AARNet's participation in this community through "best practice sharing", participation in global forums and the pursuit of innovation gives Australian researchers access to digital tools in the same timeframe as their global counterparts.

Addresses a Market Failure

The technical capabilities of AARNet are aligned to the extreme demands of research and are not available from the commercial market, and even if they were, they would (based on market testing) be unaffordable. This is made possible because AARNet Pty Ltd is a licensed telecommunications carrier which allows it to take on obligations unique to its service offerings to shareholders and customers. Fundamentally this translates to owning (or having access to) the "raw material" of telecommunications (fibre), which when combined with the technical skills and expertise of the staff employed by AARNet, allows AARNet to differentiate itself within the commercial telecommunications market.

Acquire, Pool and Leverage Assets

Fibre in the ground is an asset which has an operational lifetime approaching 50+ years which can be accumulated and traded. As a "shared entity" any fibre assets acquired by the shareholders and members as part of network expansion or connections is pooled, and can be used to secure rights to other fibre through (for example) fibre swaps with commercial providers.

This model has been proven over an extended period of time and we commend it for other national infrastructure resources that have wide consumer base. However, we do recognise that there are some specific aspects of the model, particular as they relate to the nature of the offering, may not be appropriate for every piece of infrastructure.

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

There are (at least) two aspects to this requirement – industry relevance, alignment and engagement, for a specific facility; and a level of integration and consistency across all relevant facilities/capabilities to support the research workflow.

In the first case, the requirement is very specific to each discipline and should be informed by the research stakeholders of the relevant facilities/services. Typically standards and accreditation requirements are critical to research with ethical or security concerns, or when demanded or expected by the industry sector(s) within which the research is being conducted, eg. cybersecurity and ethics in social, indigenous, health or medical, defence or software research.

4 Capability Focus Areas

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

Largely based on an analysis of the different approaches taken in Europe, in general terms there are three identifiable major trends related to national research infrastructure (more particularly, national e-Infrastructure) that have been consistent over the past 3-5 years:

1. A move to drive infrastructure operations away from ad-hoc consortia of research groups, and into for-purpose research infrastructure operators. Part of this trend is the consolidation in many countries of the NREN, the HPC/cloud organisation and the research workflow/systems integrator/identity provider into a single body that often becomes the default recipient of e-Infrastructure funding. A typical example is Norway[1], but other countries where this has happened include UK, Denmark[2], France[3], Hungary, Poland[4], Czech Republic, Italy, Finland[5], Netherlands, and Greece.
2. An attempt to associate harder metrics on the outcomes of infrastructure projects, through much stronger pre- and post-evaluation by end-user communities, publishing capabilities/service catalogues, co-design, everything-open by default (data, code, standards), and a focus on international standardisation and harmonisation.
3. Initiatives to engage SME's and industry more broadly in both the provision of research infrastructure, and as research collaborations that make use of the research infrastructure.

In short, a smaller number of entities, working under a single governance model.

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?

No response.

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

There is an emerging trend towards an increase in e-Infrastructure investments that have a larger OPEX component rather than being almost exclusively CAPEX. This is consistent with the issues raised in the capabilities issue paper.

[1] http://www.forskningsradet.no/en/Newsarticle/New_way_to_finance_national_eInfrastructure/1253993967529
[2] http://www.deic.dk/en/node/245
[3] https://www.cru.fr/en/
[4] http://www.man.poznan.pl/online/en/page/674/
[5] http://www.aka.fi/globalassets/awanhat/documents/firi/tutkimusinfrastruktuurien_strategia_ja_tiekartta_2014_en.pdf

5 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?

AARNet strongly supports the Desirable New Capabilities for Health and Medical Sciences focus area identified in section 5.3.

The **Improved Connectivity to Data and Services, End to End Data Movement** (response to Questions 30) and **Research Data Management** (Question 33) capability gaps apply to most of the New Capabilities, including

- National collaborative approach for PET tracers and cyclotrons (5.3.1) – "network of cyclotrons"
- Indigenous research platforms (5.3.2) – "centralised linkage and data clearinghouse"
- Stem Cell Therapies (5.3.4) – "Collaboration is essential", "geographically dispersed"
- Managing and leveraging research data insights (5.3.5) – "population biobank", "national health and medical big data capability"

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

No response.

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?

No Response.

6 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?

AARNet strongly supports the Desirable New Capabilities for Environment and Natural Resource Management focus area identified in section 6.3.

A specific capability gap informed by the "emerging technologies in sensors and sensors networks" and the need for a "national approach to sensor networks" (section 6.3.1) is the need for a **National Internet of Things (IoT) Sensor Network**. Without displacing ongoing research into sensors networks, such a capability would facilitate and accelerate research into the applications of IoT by providing an open platform accessible to not only researchers, but industry and the general public. This is consistent with demonstrated strong institutional interest in the establishment of sensor networks to support their own research, student engagement and industry

collaboration activities[6]. Integrating these initiatives into a national capability would support several specific research topics within the Environment and Natural Resource Management focus area including precision agriculture, environmental monitoring and management, and Smart Cities.

The capability issues paper highlights the integration of "big data" across the public and private sectors as an emerging trend in this focus area (section 6.1.1). This aligns strongly with **Improved Connectivity to Data and Services** capability gap described in the response to question 30. A number of facilities operated by this focus area are not connected to AARNet and hence fall into the **Connecting the Unconnected** capability gap (question 30).

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

No Response.

Question 20: **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?**

No Response.

7 Advanced Physics, Chemistry, Mathematics and Materials

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

AARNet has worked closely with a number of the disciplines within the Advanced Physics, Chemistry, Mathematics and Materials focus area. For example, the Emerging Capability Needs for Astronomy and Cosmology (7.2.1) and Accelerator Science (7.2.4) align strongly to the **Connecting the Unconnected** and **Asian Connectivity Parity** capability gaps detailed in the response to Question 30.

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

No Response.

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

No Response.

[6] http://meshed.com.au/community-iot-networks/

8 Understanding Cultures and Communities

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

AARNet strongly supports the Desirable New Capabilities for the Understanding Cultures and Communities focus area (section 8.3).

In an Australian context, researchers operating within this focus area need access to data and expertise (data curation, digitisation, digital preservation, citizen engagement, and knowledge exchange) that lie outside of the research sector, and inside the public sector. Shared infrastructure and working links between these communities are critical, and therefore where there are gaps or inefficiencies in research infrastructure, or ad hoc processes, which lie between these two communities, these factors operate as barriers to data availability, skills and expertise transfer, and research translation, and need to be removed.

The **Improved Connectivity to Data and Services** capability gap described in the response to question 30, is therefore critically linked to this focus. Underpinning research infrastructure needs to be extended into the national and state collecting agencies and institutions. This links the storage, transfer tools and mechanisms, networks and authentication frameworks enjoyed by the research community and unlocks the curation and data management skills and expertise these agencies. This outcome is obviously impacted by the **National Digitisation Capability**, **End to End Data Movement** (also described in the response to question 30) and **Research Data Management** capability gaps (question 33).

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

No response.

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

Recast the Understanding Cultures and Communities capability as two separate capabilities. Researchers in humanities and arts are at an early point in the transition of their research practices. Quantitative and qualitative social science research by contrast has advanced well into ubiquitous use of digital data as a research resource; in their research toolchain, compute and modelling are commonplace. A strategy that supports research innovation with the aim of having new and future types of research must be applied differently where the community needs and readiness are at different stages of computational and methodological maturity.

10 National Security

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

Consistent with the Emerging Directions and Emerging Capabilities identified in relation to cyber security research, particularly the need for a cyber national infrastructure based on a federated architecture that is "resilient, highly scalable, readily accessible at all times and flexible", AARNet believes there is a **National "CyberRange"** capability gap that would otherwise address this requirement. A "CyberRange" is a testbed and experimentation facility where cyber research, teaching, training and industry collaboration can be conducted in a secure and constrained environment, and examples now exist in regions with a cybersecurity focus, eg. Michigan Cyber Range[7], US National Cyber Range[8]. Access to the Cyberange would be facilitated by addressing the **Improved Connectivity to Data and Services** capability gap (question 30).

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

No response.

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

No Response.

11 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?

Although "high capacity" is one characteristic of all NRENs, including AARNet, the capabilities that are uniquely provided by an NREN also include very low latency, very low congestion, geographic reach to campuses and instruments, and rich interconnectivity with peer NREN's and their connected research communities.

AARNet supports the Emerging Trends identified in section 10.1.

Regarding the Current Capability and Emerging Capability Needs (10.2):

10.2.2 High Capacity Networks:

AARNet currently provides a mechanism (AARNet Connect[9]) to allow research communities, services or data sets that are embedded in organisations (commercial

[7] https://www.merit.edu/cyberrange/
[8] http://securedecisions.com/national-cyber-range/
[9] https://www.aarnet.edu.au/network-and-services/cloud-services-applications/aarnet-connect

and public sector) that would otherwise not be able to become members of AARNet, to collaborate with, provide services to and share data with Australian researchers (consistent with AARNet's Access and Content Policies[10]).

Regarding the Desirable New Capabilities (10.3):

10.3.2 High Capacity Networks

As noted in the Capability Issues Paper, AARNet's network infrastructure is extensive. However, a number of facilities, instruments, campuses and regions are currently not connected to the AARNet network, which hampers access, increases operational costs, and reduces the research impact of these facilities/instruments. Lack of access to AARNet's unique broadband services also reduces the effectiveness of research and researchers in regional and remote Australia. **Connecting the Unconnected** is therefore a significant capability gap, as highlighted by these specific examples:

- Facilities/instruments at Yarragadee and Gingin, in WA, Katherine in NT, Ceduna in SA, Mount Kent in QLD, and Stawell, in VIC
- Campuses at Bundaberg, Port Lincoln, Bunbury, Gympie, Maryborough and Hervey Bay
- Regions including Southwest WA, southeast NSW/VIC

The capability gap would need to be quantified based on identifying those locations with the most strategic impact for research and for research and industry collaboration.

Universities and research facilities that AARNet connects, particularly in regional Australia, act as anchor tenants for digital infrastructure which allows other research and education organisations (such as schools, TAFE's, libraries, hospitals, etc.) to join AARNet which improves regional services. The presence of AARNet infrastructure in a region, also allows commercial telecommunications companies to enter regional markets through fibre-swap arrangements with AARNet.

Although constructed with high levels of redundancy, AARNet's backbone network has some non-redundant paths that need to be duplicated, and there are some locations that are poorly connected (not on the DWDM backbone as identified in the issues paper). Addressing this capability gap, **National Network Backbone Robustness**, ensures the continuity of research activity, which is critical given the increasing dependency on digital tools, techniques and systems. The specific locations/links that illustrate this gap are Darwin, Hobart, a southern path between South Australia and Victoria, and the corridor between Brisbane and Melbourne.

The capability issue paper identifies the significant disparity between the international broadband capacity for research to/from Australia and the US compared to Asia. This does not reflect the increasing importance of collaboration

[10] https://www.aarnet.edu.au/about-us/policies

with the Asian research community and industry to Australia. AARNet is seeking to secure additional capacity on a new subsea fibre system between Perth and Singapore to address this **Asian Connectivity Parity** gap, and there is an opportunity for co-investment to translate this "good" capacity into "great" capacity.

There is a significant disparity and inconsistency between the data access and transfer capabilities provided by AARNet nationally and internationally, and the data access and transfer capabilities provided to researchers, research groups and instruments across the boundary between AARNet and campus infrastructure of connected institutions. This **End to End Data Movement** capability gap remains a significant impediment to maximising the value and capability of the collective investments in AARNet, institutional investments in campus infrastructure, and access to any national research infrastructure. This issue is not unique to Australia and has been addressed in the United States through the National Science Foundation's (NSF's) Campus Cyberinfrastructure - Network Infrastructure and Engineering funding program (CC-NIE)[11] which "invests in improvements and re-engineering at the campus level to leverage dynamic network services to support a range of scientific data transfers and movement". Although it can be argued that these are local campus/institution issues, they impact the capacity of every researcher at every campus where this disparity exists and hence have national impact.

Many large data sets, digital services and resources, and also industry/government collaborators, happen to be hosted at organisations that are not physically connected to, or members of, AARNet. As a result, these data sets and collaborators, cannot be readily integrated into the research workflows, facilities and capabilities normally available to the AARNet-connected research community. This missing capability, **Improved Connectivity to Data and Services**, is partly addressed through the AARNet Connect service noted above, but the expansion of AARNet's physical fibre footprint is required to be able to facilitate digital access to these data sets, services and collaborators, within the public sector and industry, to the same level enjoyed by the Australian research community.

10.3.3 Access and Authentication

As the use of digital tools, techniques and systems becomes more widespread, the importance and value of the "who are you" authentication services provided by the Australian Access Foundation (AAF) have become increasingly important. With increasing use comes increasing complexity and the need to supplement these authentication services with a range of national "what are you allowed to access/do" authorisation services. **Authorisation Services** to support increasingly complex research workflows and trust models to support data access for research is a capability gap.

[11] https://www.nsf.gov/pubs/2012/nsf12541/nsf12541.htm

10.3.6 Digitisation

AARNet strongly supports the proposed **National Digitisation Capability.** AARNet is in a unique position to comment on the directions outlined in this capability, as the provider of underpinning national research infrastructure (the NREN and allied services) to the research and public sector (including cultural, social and scientific agencies with nationally significant data collections). Specifically, digital connectivity between universities, digital repositories, cultural and collecting institutions and entities that provide digitisation services, is critical to enabling this capability, perhaps by extending AARNet as outlined in the **Improved Connectivity to Data and Services** and **End to End Data Movement** capability gaps described above.

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

AARNet has collaborated with its peer NREN's ever since it was established in 1989, and further collaboration into the next decade will be fundamental to ensuring Australia's research remains digitally well-connected, and hence globally relevant.

At an underpinning infrastructure level, working with Asian NRENs directly and through the European Union funded Trans-Eurasia Information Network (TEIN)[12] will be a major element of addressing the **Asian Connectivity Parity** capability gap highlighted in the response to Question 30. Partnerships with institutions and NREN's in the Pacific, specifically the University of South Pacific, REANNZ (the New Zealand NREN), Internet2 (US NREN), ESnet (US NREN), the University of Hawaii, and NSF programs such as PIREN[13] will continue to be necessary to maximise the opportunities for Australian researchers in this region.

There are a number of specific research initiatives of national scale that AARNet is aware of which will have material impact on the underpinning network infrastructure. Examples include:

- The Coupled Model Inter-comparison Project Phase 6 (CMIP6) as part of the World Climate Research Programme
- The Square Kilometre Array (SKA), and the Australian SKA Regional Science Centre initiative,
- The Copernicus Data hub, for data provided by the European Sentinel satellites
- LHC and Belle-II Program of high energy physics

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

Question 33:

No Response.

[12] http://www.teincc.org/teincc/about/overview.do
[13] http://www.hawaii.edu/piren/

12 Data for Research and Discoverability

Question 34: Are the identified emerging directions and research infrastructure capabilities for Data for Research and Discoverability right? Are there any missing or additional needed?

AARNet strongly supports the Desirable New Directions for "Data for Research and Discoverability" (section 11.3), and believe that **Research Data Management** is a capabilities gap that is an "*emerging area and Australia needs to consolidate the gains of the past decade and create a more integrated, coherent and reliable platform to deal with data-intensive, cross-disciplinary and global collaborative research*".

Consistent with the objectives of the Australian Research Data Services (ARDS) element of the eResearch Framework paper, an integrated national approach to providing access to all data that can be of use to Australia's research sector, regardless of its location – whether within an institution, a national facility, government agency or industry – is required. Addressing the **Improved Connectivity to Data and Services** capability gap (described in the response to question 30) would facilitate this vision.

The provision of the underlying storage, in AARNet's view, is somewhat independent of this requirement. This is partly informed by the increasing interest, at both the individual researcher, institution and discipline level, for storage to be bundled with other e-Infrastructure services (eg. with HPC, or virtual laboratories). Alternatively, they are seeking to source storage from commercial/sector cloud providers (eg. Amazon Web Services, CloudStor, DropBox) that can be integrated with their research data workflow. Research data will be therefore distributed across many storage facilities and provider types. An integrated view of this distributed storage will be important component in addressing the **Research Data Management** capability gap.

Question 35: Are there any international research infrastructure collaborations or emerging projects that Australia should engage in over the next ten years and beyond?

No response.

Question 36: Is there anything else that needs to be included or considered in the 2016 Roadmap for the Data for Research and Discoverability capability area?

No response.

13 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.