

National Digital Research Infrastructure Strategy

The National Research Infrastructure Advisory Group





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The document must be attributed as the National Digital Research Infrastructure Strategy.

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Introduction

Australia is the beneficiary of internationally recognised and highly efficient research infrastructure that consistently delivers outstanding returns. This has been enabled by the implementation of strategic roadmaps and funding from successive Australian Governments, along with support from state and territory governments, universities, and research agencies.

The most recent strategic roadmap (the 2021 National Research Infrastructure (NRI) Roadmap¹) examined NRI needs, priorities and recommended:

- that the current NRI portfolio (funded by the National Collaborative Research Infrastructure Strategy² (NCRIS)) positions Australia well in its research effort and is expected to continue to do so (Finding 1).
- to establish an expert NRI Advisory Group (NRIAG)³ to drive a more effective NRI ecosystem (Recommendation 4).
- to develop a National Digital Research Infrastructure (NDRI) Strategy (Recommendation 7).
- to prepare Australia to capitalise on future opportunities (Recommendation 8), including cutting-edge NDRI.

The 2021 NRI Roadmap identified the need for an increased focus on NDRI. This was in recognition of Australia's system of NDRI as fundamental to the research and innovation effort as well as in the provision of critical support for government decision-making. This was further emphasised by the need for Australian researchers to maintain and grow international research collaboration networks and to uphold the nation's reputable global standing. Technological developments, such as quantum computing and artificial intelligence, also show the need for an increased focus on NDRI.

In response to Recommendation 4, the Australian Government established the NRIAG in late 2022. The NRIAG's Terms of Reference⁴ (ToR) task it with advising on priorities, trends, and investment opportunities to ensure that researchers have access to cutting-edge NRI.

The NDRI Strategy represents the NRIAG's advice to Government on the desired features to consider when investing in cutting-edge NDRI. This Strategy completes activities to address Recommendation 7 of the 2021 NRI Roadmap.

Recommendation 8 of the 2021 NRI Roadmap will be addressed through the development of a NDRI specific investment plan (see 'Implementation and Review').

¹ Department of Education, Australian Government, '2021 National Research Infrastructure Roadmap'. [website] (7 Apr 2022). Department of Education, < <https://www.education.gov.au/national-research-infrastructure/resources/2021-national-research-infrastructure-roadmap> > accessed 09 Jan 2024.

² Department of Education, Australian Government, 'National Collaborative Research Infrastructure Strategy (NCRIS)'. [website], (22 Aug 2022). Department of Education, < <https://www.education.gov.au/ncris> > accessed 09 Jan 2024.

³ Department of Education, Australian Government, 'The National Research Infrastructure Advisory Group'. [website], (04 Sep 2023). Department of Education, < <https://www.education.gov.au/national-research-infrastructure/advisory-group> > accessed 09 Jan 2024.

⁴ Department of Education, Australian Government, 'Terms of Reference, National Research Infrastructure (NRI) Advisory Group'. [website], (17 Jul 2023). Department of Education, < <https://www.education.gov.au/national-research-infrastructure/advisory-group/terms-reference> > accessed on 14 May 2024.



Strategy on a page summary

<p style="text-align: center;"><u>Vision</u></p> <p style="text-align: center;">User-centric design must lie at the heart of Australia’s NDRI system.</p> <p style="text-align: center;">Australian researchers, from all disciplines, should have access to cutting-edge, sovereign NDRI capabilities to continue delivering world-class research and innovation.</p>					
<p style="text-align: center;"><u>Outcome 1</u></p> <p style="text-align: center;">UNDERPINNED BY TRAINING FRAMEWORKS FOR RESEARCHERS AND NRI WORKFORCE</p> <p>Opportunity: Supporting Australia’s NDRI workforce will enhance the quality of the nation’s research.</p> <p>Challenge: Without a highly skilled NDRI workforce, Australia will not reach its full potential.</p> <p>Approach: Governments should work with NDRI providers to address staff shortages and expand workforce training opportunities.</p>	<p style="text-align: center;"><u>Outcome 2</u></p> <p style="text-align: center;">RESPONSIVE TO TECHNOLOGICAL AND SOCIETAL SHIFTS</p> <p>Opportunity: NDRI technological advancements support Australian researchers to perform unprecedented research.</p> <p>Challenge: Rapid advances and societal shifts can lead to obsolete and ineffective digital resources.</p> <p>Approach: Coordinated, expert-informed strategic planning should underscore Australia’s future NDRI system.</p>	<p style="text-align: center;"><u>Outcome 3</u></p> <p style="text-align: center;">CONSISTENT IN ITS STANDARDS FOR DATA COLLECTION, CURATION AND ACCESS</p> <p>Opportunity: Ensuring Australia’s growing volume of research data is as FAIR as possible will offer benefits to researchers.</p> <p>Challenge: Increasing volumes of research data are being generated that are not FAIR/CARE compliant.</p> <p>Approach: A sector-wide data management framework that supports FAIR/CARE compliance nationally.</p>	<p style="text-align: center;"><u>Outcome 4</u></p> <p style="text-align: center;">INTEGRATED ACROSS LEVELS OF COMPUTING AND DATA INFRASTRUCTURE</p> <p>Opportunity: A seamlessly integrated NDRI ecosystem will support Australia’s researchers.</p> <p>Challenge: Researchers have rapidly expanding NDRI demands but may lack expertise to use data efficiently and effectively.</p> <p>Approach: Pursue integrated access to different tiers of compute and shared data.</p>	<p style="text-align: center;"><u>Outcome 5</u></p> <p style="text-align: center;">CYBERSECURE, PARTICULARLY FOR NATIONAL-SCALE DATA AND COMPUTING</p> <p>Opportunity: Enforcing Australia’s NDRI cybersecurity protects nationally valuable and sensitive digital resources.</p> <p>Challenge: Cybersecurity threats are growing as research data sensitivities increase.</p> <p>Approach: NDRI providers should support assessment and mitigation of cybersecurity risks, underpinned by system-wide trust and identity solutions.</p>	<p style="text-align: center;"><u>Outcome 6</u></p> <p style="text-align: center;">MAXIMISED BY OPENLY AVAILABLE RESEARCH SOFTWARE TOOLS</p> <p>Opportunity: Supporting research software tools as critical NDRI capabilities ensures efficient and effective research conduct.</p> <p>Challenge: Software is critically important, yet its place in NDRI is not well defined.</p> <p>Approach: Research software tools should be recognised with equal importance to NDRI computing, data and networking capabilities.</p>
<p style="text-align: center;"><u>Implementation</u></p> <p style="text-align: center;">An independent NDRI Working Group will develop an NDRI Investment Plan to implement the NDRI Strategy. The NDRI Investment Plan will be underpinned by stakeholder engagement and guided by the NRI Advisory Group. The Investment Plan will be funded, implemented, and monitored through NCRIS.</p>					

Overview

This Strategy:

- outlines its Purpose.
- defines the scope of NDRI.
- identifies relevant stakeholders.
- provides guidance regarding NDRI and First Nations peoples.
- articulates a Vision as a central organising concept.
- sets out 6 priority Outcomes that support achieving the Vision.
- outlines how this Strategy will be implemented and reviewed.

Purpose

This Strategy sets out the desired features of Australia's NDRI ecosystem to ensure it can meet the rapidly growing demand for increasingly complex digital tools and services that NDRI provides. It outlines key challenges facing NDRI users and providers and articulates high level actions to address these. Achieving the outcomes of the Strategy will require coordinated action by all existing and future NDRI stakeholders (including NCRIS projects) and will need to be driven by NRI providers and governments.

Stakeholders

The NDRI Strategy is useful for:

- governments, to inform future investment decisions and cross-sector planning.
- research infrastructure providers, to inform strategic planning of data assets, computing resources, digital services, and training.
- research communities, to ensure it reflects their user needs, and to help their users understand the NDRI available, so that digital assets and resources are easily discoverable, accessible, reusable, secure and interoperable whenever possible and relevant.
- other organisations, institutions, and agencies in the digital infrastructure ecosystem to inform co-investment and coordinated delivery of NDRI services.



What is NDRI?

The 2021 NRI Roadmap defines NDRI as encompassing those digital research infrastructure components that are collectively managed and operated as coordinated facilities and services for research institutions and users across the country because they are so nationally significant or large in scale, complexity, or cost that they cannot be offered by a single institution or facility.

The importance of expertise, and the personnel who embody that expertise, in NDRI and NRI is highlighted by 2021 Roadmap, with the definition of NRI reflecting the importance of the NRI workforce. NRI is defined in the 2021 NRI Roadmap as:

... the nationally significant assets, facilities, services, and associated expertise to support leading-edge research and innovation. It is accessible to publicly and privately funded users across Australia and internationally.

Examples of digital research infrastructure include:

- highly skilled, expert NDRI personnel who serve as an essential element of Australia's NDRI ecosystem.
- data generated both for and through research.
- data management platforms, including mechanisms for sharing data, storage, and long-term management (including deletion).
- computing, including national (Tier-1) and institutional (Tier-2) high performance computing (HPC) and cloud computing.
- analysis and visualisation software tools, in particular integrated into virtual research environments.
- quantum computing capabilities.
- cybersecurity for research infrastructure.
- trust and identity services, frameworks, and persistent identifiers (PIDs).

NDRI should be seen as cross-cutting research infrastructure that underpins all fields of research. With the ever-increasing digitalisation of Australia's research sector, NDRI is expected to play a critical role in supporting Australian researchers across all disciplines. This Strategy also acknowledges that fostering a stronger NDRI ecosystem will work to ensure that world-leading- and cutting-edge research is conducted for the benefit of all Australians.

NDRI and First Nations peoples

Australian NDRI has a significant role in promoting and sustaining, ethical and responsible First Nations research across disciplines and methodologies (AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research⁵, CARE Principles for Indigenous Data Governance⁶) as well as in working towards

⁵ Australian Institute of Aboriginal and Torres Strait Islander Studies (AIATSIS), 'AIATSIS Code of Ethics for Aboriginal and Torres Strait Islander Research (the AIATSIS Code)'. [website], (Oct 2020). AIATSIS, < <https://aiatsis.gov.au/research/ethical-research/code-ethics> > accessed 09 Jan 2024.

⁶ Global Indigenous Data Alliance (GIDA), 'Care Principles Global Indigenous Data Alliance' Global Indigenous Data Alliance [website] < <https://www.gida-global.org/care> > accessed 10 Jul 2024.



commitments to improve the outcomes of First Nations peoples (Closing the Gap⁷, Priority Reform 4). Australia's NDRI should ensure appropriate support and governance structures to enable First Nations peoples' equitable participation within the NRI ecosystem.

Due to the underpinning nature of digital capabilities, NDRI has a central role in making the entire NRI ecosystem more equitable, accessible, and connected. This extends to regional, remote and First Nations researchers. NRI that caters to diverse research disciplines (for example, science, technology, engineering, mathematics (STEM), humanities, arts, social sciences (HASS) and First Nations studies) and communities of practice are an important part of the digital research infrastructure landscape and should be addressed in the implementation of this Strategy.

In developing Australia's NDRI workforce, efforts should extend to incorporating cultural awareness training programs and applied knowledge in relation to First Nations research protocols, ethics, data governance and data management. These may include, but are not limited to, First Nations cultural awareness training, training around the application of the CARE principles for Indigenous data and the rights of First Nations peoples to their data, data about them and their cultures. With the anticipated expansion of Australia's NDRI workforce, efforts should also be focused towards increasing the employment and promoting the involvement of First Nations peoples within the NDRI ecosystem. This includes providing training and upskilling as necessary to ensure the collective benefit from data while also improving data collection, management and minimising any potential impact on First Nations peoples, communities, and cultural practices.

It is essential that NDRI data practices support the employment of appropriate First Nations data governance protocols and principles⁸. This should also address the importance of curating nationally significant data collections, ensuring that both high quality and the right data is retained in accordance with FAIR principles^{9,10} (to enable reuse in research, public policy, and industry) and CARE principles (to ensure that First Nations governance over First Nations data and its uses is respected). This is particularly relevant in the HASS disciplines, in the context of repositories and collections of data and is outlined in the Vancouver Statement on Collections-as-Data¹¹. It is also important to establish formal partnerships and shared decision-making with First Nations peoples (including First Nations Community Controlled Services and Organisations) and develop measures of data governance, capability, readiness, and preparedness. Where possible, First Nations identifiers and/or metadata (such as AustLang Codes) should be used to improve findability of First Nations data assets for all researchers and First Nations peoples.

⁷ Closing the Gap, 'National Agreement on Closing the Gap | Closing the Gap' [website] < <https://www.closingthegap.gov.au/national-agreement> > accessed 29 Apr 2024.

⁸ National Indigenous Australians Agency (NIAA), Australian Government, 'Framework for Governance of Indigenous Data | NIAA' [website] (2024) < <https://www.niaa.gov.au/resource-centre/framework-governance-indigenous-data> > accessed 08 Jul 2024.

⁹ 'Worldfair - Codata, the Committee on Data for Science and Technology' CODATA, the Committee on Data for Science and Technology [website] (01 Feb. 2023) < <https://codata.org/initiatives/decadal-programme2/worldfair/> > accessed 29 Apr 2024.

¹⁰ The Australian Research Data Commons (ARDC), 'Fair Principles for Research Data Management | ARDC'. [website] (2022). ARDC, < <https://ardc.edu.au/resource/fair-data/> > accessed 09 Jan 2024.

¹¹ Padilla, T., Scates Kettler, H., Varner, S., & Shorish, Y. (2023). Vancouver Statement on Collections as Data. Zenodo. <https://doi.org/10.5281/zenodo.8342171>.



Vision for future NDRI ecosystem

User-centric design must lie at the heart of Australia's NDRI system.

Australian researchers, from as many disciplines as possible, should have access to an integrated suite of cutting-edge, sovereign NDRI capabilities to continue delivering world-class research and innovation.

User-centric design is framed by:

- the definition of NDRI, particularly in relation to scale.
- the NRI Principles in the 2021 NRI Roadmap, to maximise capability, and focus on achieving maximum impact in national priority areas.
- the NRI Investment Principles in the 2021 NRI Roadmap,
 - to ensure investment in areas of national significance that demonstrably support Australia's research and innovation system, and
 - to develop a cohesive suite of NDRI capabilities.

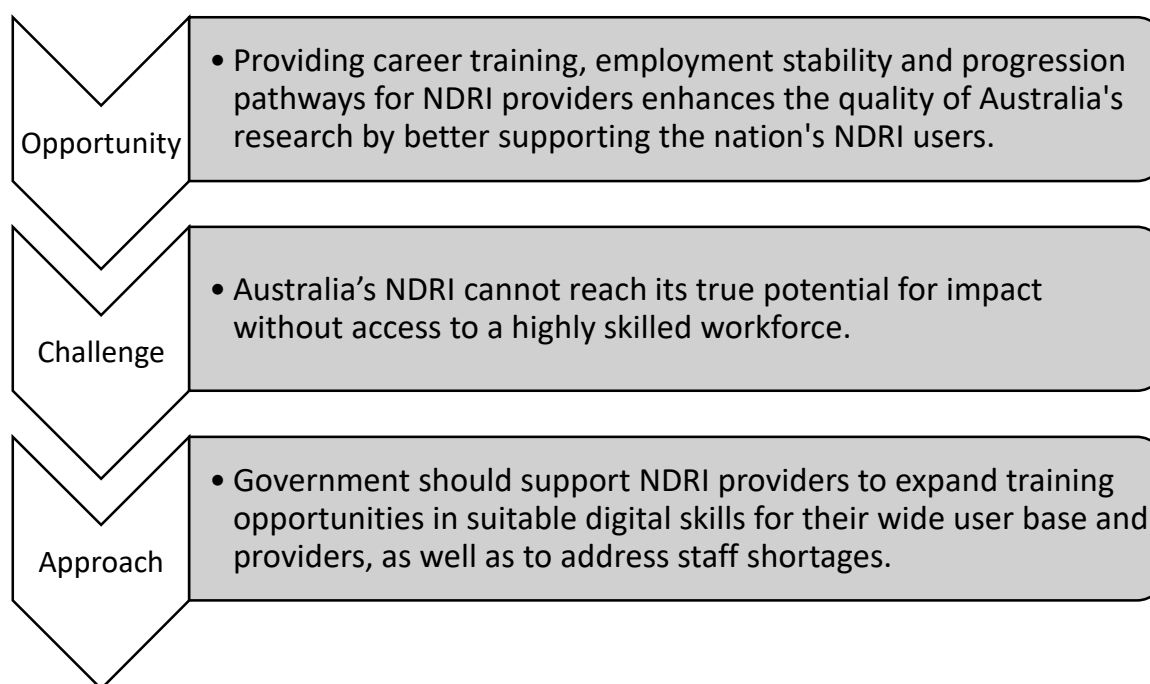
Outcomes

By 2030, Australia's NDRI system should be:

1. underpinned by training frameworks for researchers and NRI workforce.
2. responsive to technological and societal shifts.
3. consistent in its standards for data collection, curation, and access.
4. integrated across levels of computing and data infrastructure.
5. cybersecure, particularly for national-scale data and computing.
6. maximised by openly available research software tools.



1. Underpinned by training frameworks for researchers and NRI workforce



Opportunity – Providing career training, employment stability and progression pathways for NDRI providers enhances the quality of Australia's research by better supporting the nation's NDRI users.

The strength of Australia's NDRI ecosystem will always be underpinned by highly skilled, expert personnel responsible for operating the nation's NDRI capabilities. Supporting NDRI providers to nurture their workforces will offer many benefits, including (but not limited to), attracting, and retaining invaluable personnel in a competitive global hiring market. An empowered NDRI workforce will ultimately support all Australian researchers, across all disciplines, to maximise the efficient and effective use of the nation's NDRI to continue achieving high quality, impactful research.

An NCRIS Case Study

Bioplatforms Australia supported the Australian BioCommons in response to the growing emergence of digital resources in life sciences research. This support included a planned series of upskilling activities for personnel. The success of these events was realised in the LEVEL of attendees and subsequent post-event visits, which has driven a large increase in number of registered users from Australian Universities and independent research institutions.

Challenge – Australia's NDRI cannot reach its true potential for impact without access to a highly skilled workforce.

The increased importance and demand for NDRI by diverse users also create growing demand for a diverse and highly specialised expert workforce that is able to maintain and operate NDRI to maximise the value of capital investment. Global shortages are driving a highly competitive global environment for digital experts, such as research computing specialists, research data specialists and research software engineers. In this environment, Australian NDRI critically relies on appropriate training and career pathways within Australian NDRI.



The widening user base of NDRI, across various research disciplines and sectors, (for example, reaching into the use of data to develop policy) is growing the needs and expectations for training opportunities in the digital skills necessary to ensure that NDRI resources are used to their full potential. Though many training opportunities already exist, they are often not easy to find and/or accessible to the user base.

Approach – Government should support NDRI providers to expand training opportunities in suitable digital skills for their wide user base and providers, as well as to address staff shortages.

NRI-system wide opportunities to address training frameworks will be considered during the development of the NRI Workforce Strategy, as well as in the context of the next NRI Roadmap, planned for release in 2026.

Also, many NDRI providers currently support training opportunities in digital skills for digital specialists and their users, across all levels of experience and expertise. This training community extends to the teachers and trainers of digital skills and NDRI. It extends across all levels of education including (but not limited to) tertiary education. It is essential that NDRI providers build on existing activities, such as the Digital Research Skills Australasia (DReSA)¹² and the Digital Research Capabilities and Skills Framework¹³, to pursue the development of a common framework. A framework will support the uplift of digital researcher skills through national and international collaborations, as well as enable training opportunities to be clearly communicated to digital specialists and potential users.

Investments in the NDRI workforce should align with delivering research agendas of national significance while also supporting domain-specific training requirements that use specialised NDRI. Existing Australian Government initiatives, such as the Diversity in STEM (DiSTEM) Review¹⁴, will also complement this outcome. NDRI investments that support sustainable career pathways should also consider complementary education and training qualifications already on offer.

In ensuring equitable access to Australia's NDRI, and broader support for its workforce and users, it's important to consider meeting the needs of individuals with disabilities, those who do not speak English as a first language, those who require accessibility aids, and the rights of individuals to participate in decision-making related to their data.

NDRI providers are also encouraged to ensure the provision of career development opportunities for the NDRI workforce to attract and retain staff with the required expertise. This will be a key issue for focus in the NRI Workforce Strategy.

The Government should use existing and planned activities in skills sector reforms to address shortages, support the training and upskilling and retention of a digitally skilled workforce amid increasing competition between the academic and industry sectors, globally. This could include linking in with activities reviewing how research assessment affects research culture and the careers of

¹² Digital Research Skills Australasia, 'Welcome to Digital Research Skills Australasia (DReSA)'. [website], < <https://dresa.org.au/> > accessed 09 Jan 2024.

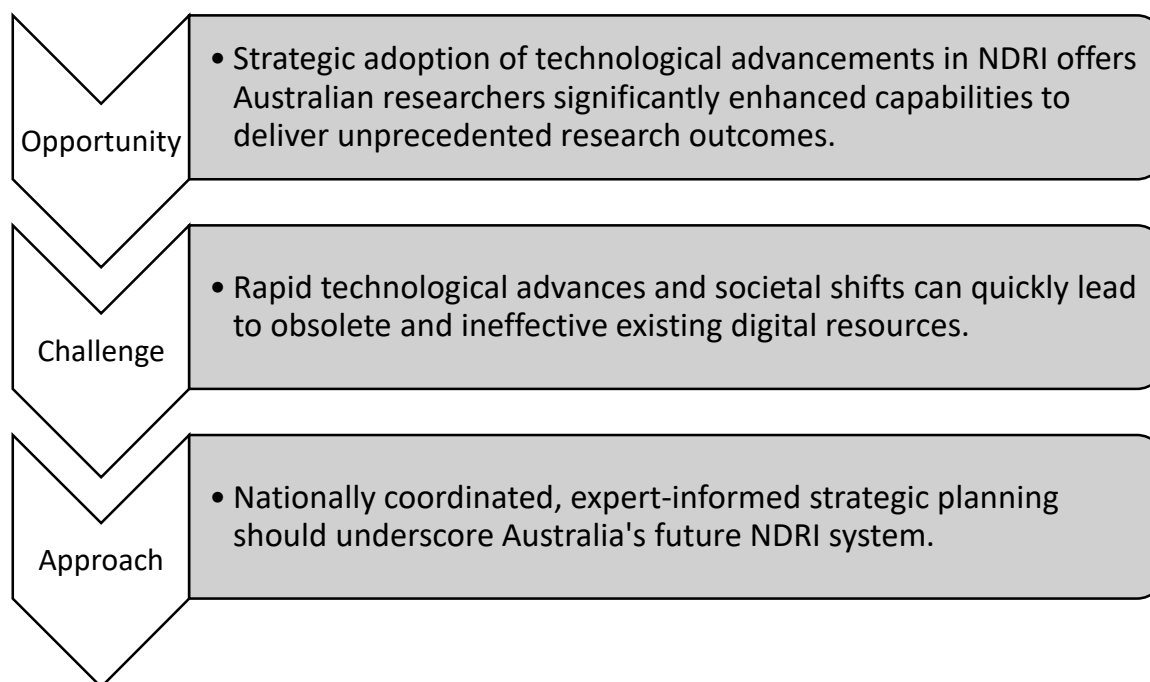
¹³ The Australian Research Data Commons (ARDC), 'A Framework for Australia's Digital Research Skills | ARDC'. [website] (23 Nov 2023). ARDC, < <https://ardc.edu.au/case-study/a-framework-for-australias-digital-research-skills/> > accessed 29 Apr 2024.

¹⁴ Department of Industry, Science and Resources, Australian Government, 'Pathway to Diversity in STEM Review Final Recommendations Report'. [website] (2023), < <https://www.industry.gov.au/publications/pathway-diversity-stem-review-final-recommendations-report> > accessed 29 Apr 2024.



Australian researchers¹⁵ as well as skilled migration reform, such as the Australian Government's Migration Strategy¹⁶.

2. Responsive to technological and societal shifts



Opportunity – Strategic adoption of technological advancements in NDRI offers Australian researchers significantly enhanced capabilities to deliver unprecedented research outcomes.

Advances in digital technologies can enable Australian researchers to now deliver outcomes that may have not been (practically) possible in the past¹⁷. The strategic uptake of new and emerging digital tools within the nation's NDRI ecosystem will support all researchers to access state-of-the-art capabilities to conduct innovative and pioneering research. These research outcomes may offer unprecedented benefits for all Australians while aligning with the nation's strategic interests.

An NCRIS Case Study

The Australian BioCommons with its delivery partners, the Queensland Cyber Infrastructure Foundation (QCIF) and The University of Melbourne, provide an Australian AlphaFold Service¹⁸. AlphaFold is an artificial intelligence (AI) system that predicts a protein's 3D structure from its amino acid sequence. The Australian AlphaFold Service supports Australian-based researchers by offering

¹⁵ Office of the Chief Scientist, Australian Government, 'Research Assessment in Australia: Evidence for Modernisation | Chief Scientist' [website] < <https://www.chiefscientist.gov.au/ResearchAssessment> > accessed 10 Jul 2024.

¹⁶ Department of Home Affairs, Australian Government, 'Migration Strategy'. [website], (23 Feb 2024). Department of Home Affairs Website, < <https://immi.homeaffairs.gov.au/what-we-do/migration-strategy> > accessed 29 Apr 2024.

¹⁷ Academy of the Social Sciences in Australia, 'Decadal Plan for Social Science Research Infrastructure 2024-33' Academy of the Social Sciences in Australia [website] < <https://socialsciences.org.au/projects/decadal-plan/> > accessed 10 Jul 2024.

Australian Academy of Science, 'Preparing for Australia's Digital Future: A Strategic Plan for Information and Communication Science, Engineering and Technology | Australian Academy of Science' [website] < <https://www.science.org.au/support/analysis/decadal-plans/ics/preparing-australias-digital-future> > accessed 10 Jul 2024.

¹⁸ Australian BioCommons, 'Australian AlphaFold Service Australian BioCommons' Australian BioCommons [website] (n.d.) < <https://www.biocommons.org.au/alphafold> > accessed 04 Jun 2024.



the research infrastructure (for example, expertise and underlying graphics processing unit (GPU) hardware) that enables researchers to efficiently and effectively maximise AlphaFold’s capabilities.

Challenge – Rapid technological advances and societal shifts can quickly lead to obsolete and ineffective existing digital resources.

Rapidly evolving digital technologies represent great opportunities to progress research discovery and innovation. However, this also comes with a profound risk of obsolescence if not appropriately managed.

Known drivers of technological and societal change include:

- the speed of development in HPC, accompanied by increasingly diverse hardware architectures that create massive demands for data storage, as well as reductions in code portability and other software requirements and increased capital costs and power usage.
- increased adoption of digitally-driven applications, such as AI, machine learning (ML), generative AI and large language models (LLMs), which could lead to exponential growth in the potential for research to solve complex problems – as well as the demand for computing, data, software, and networking capabilities.
- digitally driven applications and software are creating new needs that will need to be met through diverse computing setups (high-throughput, cloud, and edge computing).
- new advanced computing technologies such as quantum computing, and new instruments and sensors which produce ever larger volumes of data of increasing complexity, requiring increased availability of these capabilities to a wider range of users.
- trust and identity solutions that are globally aligned to prepare for future cybersecurity risks and technology disruptors.
- climate and environmental challenges will drive the demand for more sustainable and energy efficient systems, particularly in accordance with the Australian Government’s Net Zero greenhouse gas emission target by 2050¹⁹.
- responses to a dynamic international geopolitical environment.

Technological advancements also create societal shifts, and corresponding new public policy that must be considered to ensure impact of NDRI-supported research and innovation.

Known examples of societal shift and public policies include:

- public interest and use of AI
- the UNESCO Recommendation on Open Science²⁰
- the OECD’s Recommendation of the Council on Enhancing Access to and Sharing of Data²¹
- society’s attitude towards the collection, use and disclosure of sensitive information.
- privacy policy reforms

¹⁹ Department of Climate Change, Energy, the Environment and Water, Australian Government, 'Net Zero - Dcceew'. [website] (2022). < <https://www.dcceew.gov.au/climate-change/emissions-reduction/net-zero> > accessed 09 Jan 2024.

²⁰ UNESCO, 'UNESCO Recommendation on Open Science'. [website], (21 Sep 2023), UNESCO. < <https://www.unesco.org/en/open-science/about> > accessed 09 Jan 2024.

²¹ OECD, 'Recommendation of the Council on Enhancing Access to and Sharing of Data'. [website], (06 Oct 2021), OECD Legal Instruments. < <https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0463> > accessed 09 Jan 2024.



- the UN Sustainable Development Goals²²
- Government digital and data strategies and requirements
- the UN Declaration on the Rights of Indigenous Peoples²³.

It is imperative that Australia's NDRI ecosystem is prepared to adapt to these changes and can capitalise on the opportunities they present while mitigating against potential concerns. It is also critical that the NDRI Strategy is aligned with the broader system of relevant government activities, including the List of Critical Technologies²⁴, the National Science and Research Priorities²⁵ and the Australian Government's interim response to safe and responsible AI consultation²⁶. A whole of government approach will greatly support the delivery of this outcome and the broader NDRI Strategy.

Approach – Nationally coordinated, expert-informed strategic planning should underscore Australia's future NDRI system.

Coordinated, well-formed planning is essential to ensure Australia's NDRI is prepared to both address and adapt to current and emerging technological developments. This includes providing the flexibility to ensure the system is agile and well-gearred to respond to unforeseen shifts. These shifts include those not yet realised in the space of AI/ML and the increasing demand for cloud-based capabilities (commercial or otherwise) that may also help address the scalability and plasticity required for Australia's growing NDRI landscape. Investment in NDRI should take up lessons from other activities, such as the findings from the Special Report for the US Department of Energy, Summary and Analysis of Major Government Funded HPC Centers' Procurement Processes²⁷.

The individual and collective expertise of NCRIS projects should also be directed towards supporting or spearheading domestic and international activities that respond to disruptive shifts. The Government should use NCRIS investment and existing relevant groupings to drive expectations for shared planning among funded organisations. It should also have clear expectations that funded organisations remain informed about the NDRI needs of the research communities and other users they support, including users from multiple domains. Incentivising long-term partnerships among NDRI providers with communities of researchers and users should also be strongly considered. This will ensure a shared approach to fore-sighting and responding to emerging and future changes in the interests of Australian NDRI users.

Government should also use its available resources, including the NRIAG and government stakeholders, to ensure that the NDRI Strategy remains current, that investment is sound and

²² UN, 'The Sustainable Development Goals'. [website] (2023), United Nations Sustainable Development, < <https://www.un.org/sustainabledevelopment/> > accessed 09 Jan 2024.

²³ UN, 'United Nations Declaration on the Rights of Indigenous Peoples | Division for Inclusive Social Development' [website] < <https://social.desa.un.org/issues/indigenous-peoples/united-nations-declaration-on-the-rights-of-indigenous-peoples> > accessed 29 Apr 2024.

²⁴ Department of Industry, Science and Resources, Australian Government, 'Critical Technologies Statement'. [website], (19 May 2023). < <https://www.industry.gov.au/publications/critical-technologies-statement> > accessed 09 Jan 2024.

²⁵ Department of Industry, Science and Resources, Australian Government, [website] (07 Sep 2023), Australia's Draft National Science and Research Priorities, < <https://consult.industry.gov.au/sciencepriorities2> > accessed 09 Jan 2024.

²⁶ Department of Industry, Science and Resources, Australian Government, 'The Australian Government's interim response to safe and responsible AI consultation'. [website], (17 Jan 2024). < <https://www.industry.gov.au/news/australian-governments-interim-response-safe-and-responsible-ai-consultation> > accessed 29 Apr 2024.

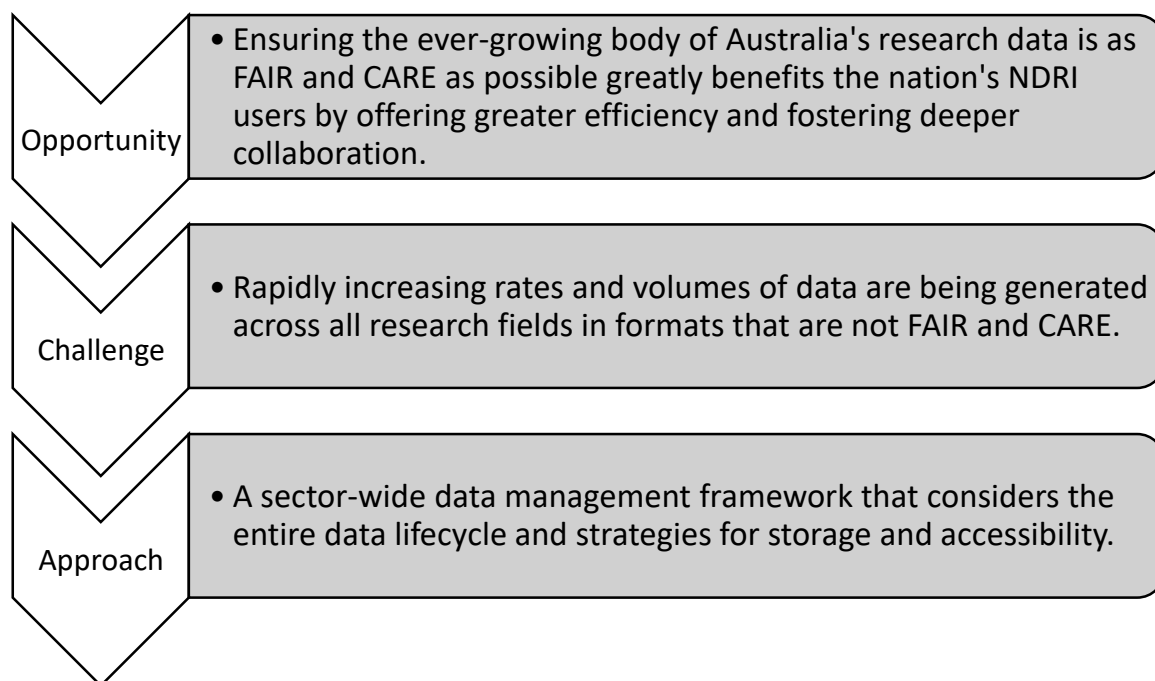
²⁷ Bob, Sorensen, and Tom Sorensen, *Special Report for the US Department of Energy Summary and Analysis of Major Government Funded HPC Centers' Procurement Processes*, HR4.0440.10.10.2023 (Hyperion Research, 2023).



cognisant of emerging and future developments, and that there is alignment across NDRI-related government and other sector-wide programs and policies.

Further considerations should also extend to First Nations peoples and any additional or alternative data they may wish to see collected in delivering this outcome. First Nations data practitioners and knowledge holders are part of the 'expert-informed strategic planners' and must hold an active role within the strategic planning process.

3. Consistent in its standards for data collection, curation, and access.



Opportunity – Ensuring the ever-growing body of Australia's research data is as FAIR and CARE as possible greatly benefits the nation's NDRI users by offering greater efficiency and fostering deeper collaboration.

Enabling Australian researchers to re-use and re-analyse high-quality datasets will maximise the efficiency of the nation's collective research efforts. Supporting Australia's NDRI to generate (and manage) datasets that are as FAIR as possible will support researchers, from all disciplines, to have more capability to dedicate efforts towards other aspects of their research. This will help achieve an overall increase in the nation's research productivity. Greater standards of collection, curation and access will also ensure that unnecessary 'data debris' is minimised.

Australia's researchers should also uphold the CARE Principles for Indigenous Data Governance when handling, managing, and analysing First Nations peoples' data. The CARE Principles represent the crucial role of data in advancing innovation efforts while respecting the purpose behind the data and the right to self-determination for First Nations peoples.



An NCRIS Case Study

AuScope, National Computational Infrastructure (NCI), Australian Research Data Commons (ARDC) and Australia's Terrestrial Ecosystem Research Network (TERN) collaboratively developed the Geophysics 2030 project²⁸. The project provides standards for data collection, curation, and access by:

- the adoption of international standards
- vertical integration of datasets
- co-location with computing resources
- development of community software and environments
- training and capacity building.

This activity has created a new high-performance dataset and introduced a world-leading community platform that allows researchers to combine HPC, high-resolution datasets and agile software workflows. As a result of this project, Australia's national geophysical datasets have a pathway to meet the FAIR data principles, achieve sustainability and contribute to innovative high-impact research in the coming decades.

Challenge – Rapidly increasing rates and volumes of data are being generated across all research fields in formats that are not FAIR and CARE.

Data is at the heart of 'digital' and is both a critical enabler of research and a crucial asset to empower and inspire future discovery. Data is also an intrinsic element of research itself. Data shapes the scientific questions and impacts the design of focussed experiments and monitoring programs. Data also influences the conduct of research itself, including testing theories, development of algorithms and models, and presentation of the evidence that will drive research translation. Access to and use of data, together with full contextual metadata, stimulates and empowers collaboration within and across disciplines. Access to data also empowers other activities, such as informing policy development. Consequently, access to high quality data is a fundamental driver of excellence in research and innovation. The enabling power of data also represents an investment in future research opportunities, both to extend the scope and timeline for responding to as yet unposed science questions and collaborations, and to test the validity of future hypotheses.

This Strategy highlights the intrinsic value of data as an integral component of digital infrastructure. It is an opportunity to recognise data beyond the mechanisms to access, share and process it, but to also consider it considering the policies, tools and skills needed to manage, store, and sustain this vital asset for collaboration and inspiration. Key identified barriers are:

- poor data management practices, including restrictive or local access conditions.
- the ever-increasing complexity of data being generated and handled.
- incompatible metadata standards and formats.
- incompatible or siloed information systems.
- a lack of archiving mechanisms that ensure that data is available for reuse (including in new ways).
- challenges faced in discovering relevant research.

²⁸ AuScope, 'Geophysics 2030: Modernising Geophysics for Large-scale Computing', [website] (19 Dec 2023) AuScope < <https://www.auscope.org.au/posts/geophysics-2030-modernising-geophysics-for-large-scale-computing> > accessed 04 Jun 2024.



These issues are compounded by the exponentially rising volumes of data created through modern research practices, from both publicly funded research and private and commercial research entities. Significant amounts of data are generated and held in government administrative datasets and by private-sector organisations, which may not be accessible to the broader research community. Large volumes of data can be easily and rapidly generated from diverse applications. This creates immense potential for value for the use, reuse, and new application of data across domains and disciplines. However, this potential is only achievable with careful consideration of the data's whole-of-lifecycle needs.

Many research infrastructure facilities rapidly generate large datasets (for example, from high-resolution instruments), which increases demand for storage and would be unsustainable without data management frameworks – and clear prioritisation of data assets. In addition, it is often unclear with whom the responsibility for the long-term storage of this data lies. In the research sector, collaboration often maximises returns on investment, therefore digital research infrastructure needs to provide access to diverse creators and users of data across research, government, and industry. This creates challenges in relation to the differing access needs between the types of datasets, for example, between open access research and commercially confidential projects. Compounding these challenges is that the uptake of new and disruptive technologies will require continued review of any established standards, to ensure ongoing applicability and that these standards are fit-for-purpose.

Approach – A sector-wide data management framework that considers the entire data lifecycle and strategies for storage and accessibility.

These issues require a sector-wide data management framework that considers the entire data lifecycle from creation to deletion and includes clear metadata and access standards. Building upon the Research Data Management Framework for Institutions²⁹, any future framework should be employed by NCRIS facilities and adopted by members of the wider research community, including (but not limited to) university-affiliated research institutions and government-associated agencies. To be effective, this will require broad consensus and encapsulate best practice without being overly restrictive, considering the diverse nature and obligations of the organisations that create and process research data. Major data producing research infrastructure have an important role to play by being integrated into the data lifecycle from the point of capture. Standards (including those for data collection, curation, and access) often have international origins, and are well established and contextualised within specific domains of research, hence maintaining a level of consistency with any existing international standards will be important for delivering this outcome.

Further guidance is available in the Data Availability and Reuse Productivity Commission Inquiry Report³⁰ as well as other relevant international guidelines, including the UNESCO Recommendation on Open Science, to enable NDRI providers and research communities to identify and prioritise nationally significant datasets.

²⁹ The Australian Research Data Commons (ARDC), 'Research Data Management Framework for Institutions | ARDC'. [website] (15 Apr 2024). ARDC, <<https://ardc.edu.au/resource/research-data-management-framework-for-institutions/>> accessed 29 Apr 2024.

³⁰ The Productivity Commission, Australian Government, 'Data Availability and Use Inquiry Report'. [website], (08 May 2017), The Productivity Commission. <<https://www.pc.gov.au/inquiries/completed/data-access/report>> accessed 09 Jan 2024.



The development and adoption of a consistent data management framework across NCRIS and the broader research sector should aim to deliver:

- highly trained, expert digital specialists needed for implementing and sustaining standards, especially for NDRI.
- a unified approach toward data and software interoperability protocols, that accommodates the distinct requirements of different data communities and international obligations.
- easy access to the community-wide tools for data upload and migration.
- recognition that streamlined access to government data is an important feature of the national research agenda in many disciplines³¹.
- data access in complex collaborative environments to be as open as possible, as closed as necessary, and to prevent the potential duplication of research efforts.
- consistent use of appropriate informatics standards for data structures, semantics, PIDs (alignment with the Australian National PID Strategy and Roadmap³²) and metadata.
- coordination of data storage capacity with appropriate levels of redundancy.
- planning for the entire data lifecycle, including:
 - national data governance policy to meet wider policy needs.
 - the ability to capture data, metadata, provenance capture and appropriate pre-processing.
 - a common approach to data linkage and integration within and across disciplines.
 - long-term archiving and digital preservation of nationally significant datasets in accordance with the FAIR and CARE principles, and to ensure that First Nations governance applies to First Nations data and its uses are respected.
 - efficient curation of nationally significant datasets.
 - end-of-lifecycle data disposal (accounting for data of varying research value, ranging from transient to longer-term referential or sovereign importance).
 - any financial and economic implications.
 - clear delineation of responsibilities across the data lifecycle.

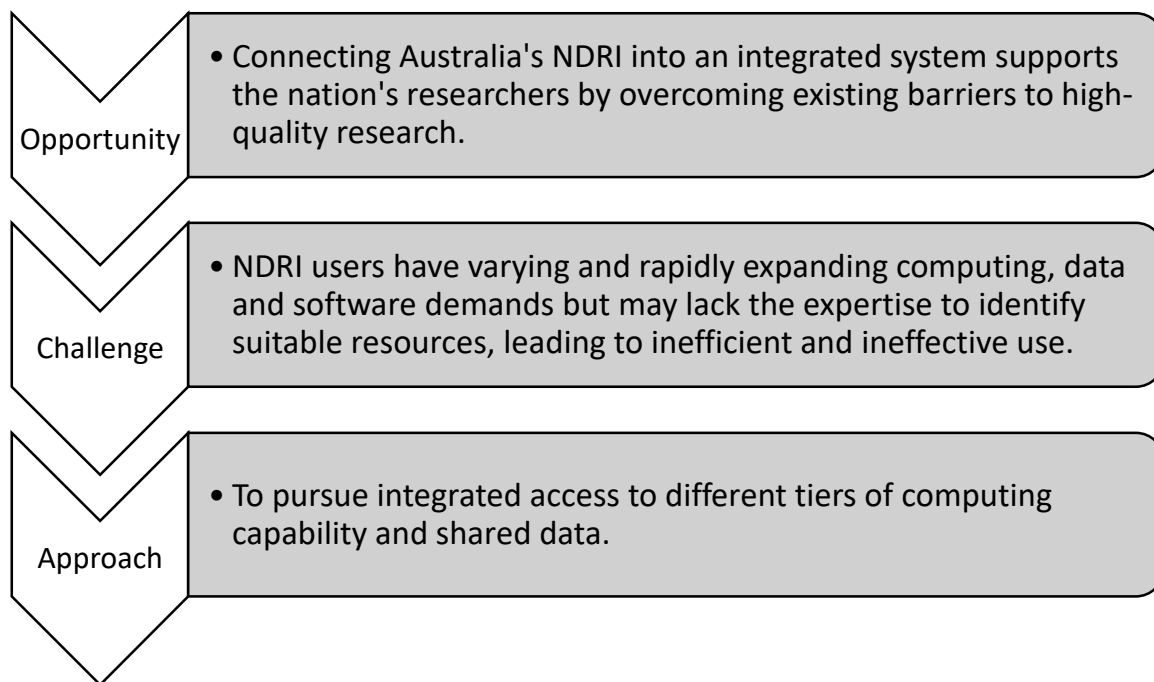
Creating a single consistent framework across all research disciplines, as relevant as possible to other data users, will be challenging. The Government should focus existing NDRI efforts on the development of research data management policies and frameworks, to ensure a unified approach and common strategic intent across different stakeholders, organisations, and projects. NCRIS projects with expertise in this area and that are already leading national and international efforts should also play a leadership role in the design and implementation. It is important to note that a data management framework alone will not deliver a real-world business model for the storage and archiving of significant research datasets. In implementing the NDRI Strategy, the Government should work with stakeholders to identify and prioritise the most appropriate solutions to the long-term storage of significant research datasets. Considerations may also extend to understanding potential incentives to promote and reward users in making their data FAIR and CARE compliant.

³¹ Australian Bureau of Statistics (ABS), 'ABS/Universities Australia Agreement'. [website], (1 Jan 2024), ABS < <https://www.abs.gov.au/statistics/microdata-tablebuilder/absuniversities-australia-agreement>> accessed 27 June 2024.

³² The Australian Research Data Commons (ARDC), 'Australian National Persistent Identifier (PID) Strategy and Roadmap | ARDC'. [website] (2023), ARDC, < <https://ardc.edu.au/project/australian-national-persistent-identifier-pid-strategy-and-roadmap/>> accessed 09 Jan 2024.



4. Integrated across levels of computing and data infrastructure



Opportunity – Connecting Australia's NDRI into an integrated system supports the nation's researchers by overcoming existing barriers to high-quality research.

Increased harmony and interoperability across Australia's NDRI will streamline research processes for end-users. The creation of mapped pathways for researchers to transition between disparate levels of infrastructure and across different fields of research will save Australia's researchers time, effort and resources and should increase overall research productivity nationally.

An NCRIS Case Study

The ARDC Nectar Research Cloud (Nectar)³³ provides Australia's research community with fast, interactive, self-service access to large-scale computing infrastructure, software, and data. It allows researchers and research support staff to access compute resources, software, and data from any setting (for example, work or home offices) and share them with collaborators at other institutions. Nectar is co-designed and receives co-investment from universities across Australia. This federation enables cross-institutional research collaborations to deliver research computing services at a national scale.

Challenge – NDRI users have varying, and rapidly expanding computing, data and software demands but may lack the expertise to identify suitable resources, leading to inefficient and ineffective use.

The increasingly diverse nature of problems that NDRI help solve creates a growing need for seamless access between different computing, data, and software offerings, for users with varying levels of expertise, experience, and digital literacy.

³³ The Australian Research Data Commons (ARDC), 'ARDC Nectar Research Cloud | ARDC'. [website] (n.d.) < <https://ardc.edu.au/services/ardc-nectar-research-cloud/> > accessed 04 Jun 2024.



In addition to the existing suite of NCRIS-supported facilities, there is a growing array of institutional, international, and commercial offerings available to digital research infrastructure users. Selecting the most appropriate resource can be challenging for users who are not NDRI experts. There is often a need to move between levels of computing and data, for example, across levels of computing when a successful trial needs to be scaled up and accessing compute for the analysis of data. Moreover, many communities require compute that is operated in a specialised way.

A lack of interoperability and integration between all these resources creates barriers for user access, inefficiencies in resource utilisation, and further compounds redundancies with data and coding.

Approach – To pursue integrated access to different tiers of computing capability and shared data.

To drive the transdisciplinary approaches that will extract the full value of NDRI investment, different research and broader user communities need to easily access different tiers of computing capability and shared data.

Linked NDRI is needed to allow research communities and other users to move seamlessly between these offerings at the national and institutional levels. Achieving this, could, for example, allow ongoing operation of NDRI despite unexpected system interruptions (such as natural disasters) and help in addressing unnecessary duplications of efforts and resources between research organisations utilising Australia's NDRI. Future investments in Australia's NDRI capabilities should consider user experiences in accessing NDRI and refer to the NRI Roadmap's case study, titled '*the value of a clear digital research infrastructure strategy.*'

This requires:

- highly trained, digital specialists to support and optimise NDRI-related research tools.
- scalable computing capability to support large-scale NDRI projects.
- frameworks that encourage institutional resources to interface with national capabilities to support a seamless experience for users.
- NDRI cloud capabilities that alleviate demand for on-premises HPC and interoperability with the broader cloud ecosystem, for example, AI-ready cloud compute and tensor processing units.
- flexible access schemes that enable a variety of users, including periodic and early users, to access HPC and other computing capabilities.
- co-location of data and computing, where necessary.
- federated data and access platforms, where multiple databases can be accessed as one, while offering secure research environments for sensitive data.
- consistent and national approach to services, tools, workflows, and governance.
- integration between major data producers and data processing and storage capabilities that allow automation.
- specialised and fit-for-purpose computing solutions that use national-scale capabilities.
- a more connected governance framework for national-level (Tier-1) HPC and data to support efficient shared planning of upgrade and replacement needs.
- trust and identity services that enable seamless and consistent access across the system, supporting movement between levels of computing and infrastructure, and preventing inefficiencies in resource utilisation and redundancies with data and coding.

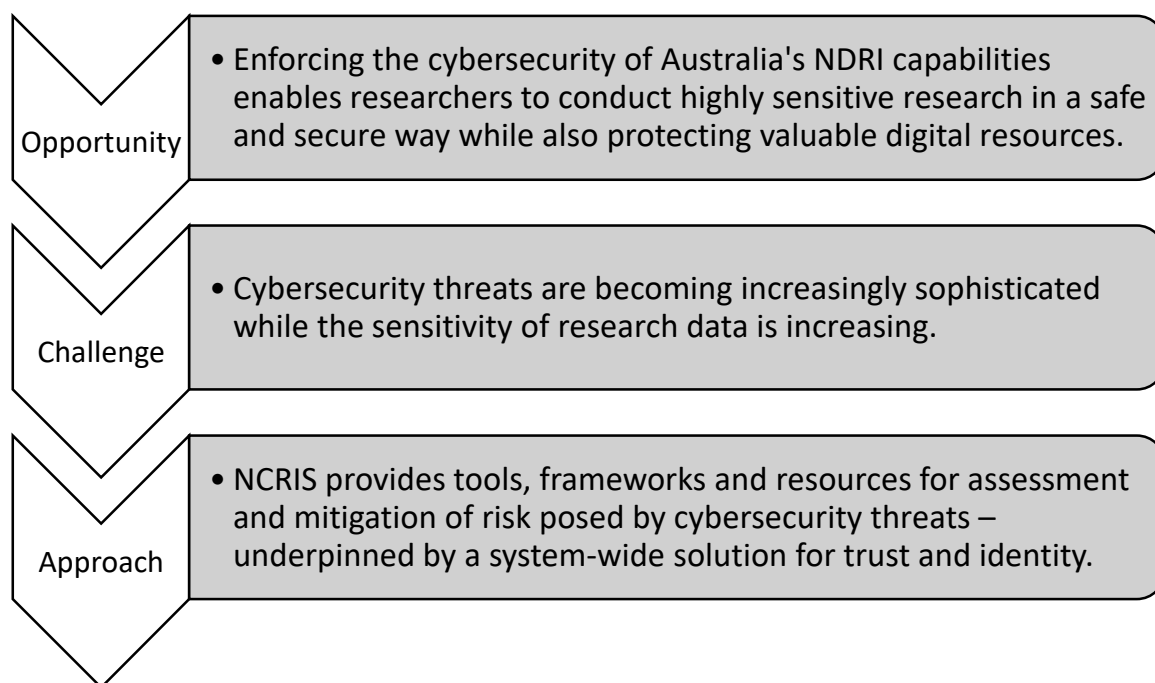


The technical challenges associated with the integration of such a wide array of resources are considerable and must also account for legal, privacy and cultural considerations.

A staged approach will be necessary, building upon existing NDRI efforts to develop locally seamless user experiences that can then be elevated nationally. These local efforts must be well connected to ensure compatibility and better integration in the future. It is necessary to coordinate with other stakeholders in the research ecosystem, including international partners, particularly those who have developed their own digital research infrastructure capabilities. This also highlights the need to review and consider better connected NDRI governance frameworks to improve the integration of Australia's NDRI ecosystem.

Systematic trust and identity services and access management frameworks will be fundamental to delivering secure access to high value digital resources. These will help in standardising and simplifying access to national and institutional compute and storage resources, while also simplifying transition between tiers. These frameworks will also promote the secure connection of Australian datasets with related international datasets.

5. Cybersecure, particularly for national-scale data and computing



Opportunity – Enforcing the cybersecurity of Australia's NDRI capabilities enables researchers to conduct highly sensitive research in a safe and secure way while also protecting valuable digital resources.

Providing secure arrangements for researchers to generate, access and analyse data will always be an essential element of Australia's NDRI. These datasets (for example, sensitive and nationally valuable datasets) require ongoing and enhanced protection against ever-increasing cyber threats. By providing cybersecure NDRI, researchers can use this research infrastructure with confidence while establishing and maintaining trust with the broader Australian community that they serve.



An NCRIS Case Study

The Australian Access Federation (AAF) has partnered with the Australian BioCommons to implement a pilot federated identify and access management framework to simplify the research process by streamlining access for life science researchers³⁴. The framework provides federated identity and collaborative group management tools to the Australian BioCommons, allowing them to manage access rights, authentication, and security concerns. The framework minimises the amount of time necessary to access research data and information.

Challenge – Cybersecurity threats are becoming increasingly sophisticated while the sensitivity of research data is increasing.

In recent years, increasingly sophisticated cyber-attacks have targeted valuable digital resources and sensitive data. The far-reaching consequences of these threats impact on personal privacy, innovation, national security, and sovereignty, and are driving the need for more coordinated cross-sectoral responses.

As a central component to Australia’s research community, NDRI are a treasure trove of highly valuable resources. This is due to their immense potential for value creation and the increasing strategic importance and sensitive nature of research data handled. This Strategy recognises that the higher security treatment of data may conflict with the principles of an open science agenda. In accounting for this potential conflict of principles, a selective treatment approach tailored towards specific datasets (for example, sensitive data) could be considered.

Without a holistic approach to cybersecurity that builds resilience across Australia’s NDRI ecosystem, Australia’s digital infrastructure and its users will become increasingly vulnerable to such threats.

Approach - NCRIS provides tools, frameworks and resources for assessment and mitigation of risk posed by cybersecurity threats – underpinned by a system-wide solution for trust and identity.

As leaders in NRI and custodians of highly valuable digital resources, existing and future NCRIS facilities should prioritise the development of tools, frameworks and resources that enable the assessment and mitigation of risk posed by cybersecurity threats. Activities should include:

- benchmarking and baselining NDRI cybersecurity posture.
- post-quantum cryptography.
- designing frameworks to mitigate risk to resources, including alignment to institutional policies and procedures that set out responsibilities and reporting requirements.
- developing mechanisms to train staff, raise awareness and promote best practice among their diverse user bases.
- fostering a community of best practice across NCRIS that supports coordinated efforts, including digital preservation measures.
- implementing technologies that protect NDRI resources and their users, including (but not limited to) source code management, reproducible software builds and curated software libraries.

³⁴ The Australian Access Federation (AAF), 'The Australian BioCommons Collaborate with AAF' Australian Access Federation. [website] (05 Jul. 2022) < <https://aaf.edu.au/project/biocommons-project/> > accessed 04 Jun 2024.



These activities should be grounded in best practice approaches to combat threats. A better collective understanding of these threats will be essential to ensuring responses are proportionate and aligned. These should also align with broader national efforts, such as the Australasian Higher Education Cyber Security Service³⁵, the 2023-2030 Australian Cyber Security Strategy³⁶, Five Safes Framework³⁷, the Data Availability and Transparency Act 2022 (DATA)³⁸, and government expectations, such as in the Guidelines to Counter Foreign Interference in the Australian University Sector³⁹. Additionally, a whole of Australian Government approach towards establishing, certifying, and maintaining an accredited cybersecurity network could serve to further protect Australia's NDRI. For example, this could involve the adoption of advice in the Information Security Manual⁴⁰, and leveraging the expertise of the Australian Cyber Security Centre within the Australian Signals Directorate.

A critical step will be to augment current activities by embedding trust and identity capabilities across the current NCRIS system. This work should evolve into an ongoing NDRI capability that ensures:

- provision of an NDRI-systemwide solution for trust and identity, which may consider a collaborative and domain-orientated approach.
- alignment with the national and international cybersecurity environment.
- support for the development of trust and identity incubators that ensure trust and identity approaches mature along with NRI technologies.
- good privacy practices that are built-into the design of NCRIS resources.

A holistic trust and identity capability will standardise and simplify access for the research community to deliver a more secure, efficient, and usable research infrastructure. Trust and identity services and frameworks will help strengthen security for access to sensitive and open data and support FAIR and CARE data.

This Strategy acknowledges that research carries an inherent level of risk. Understanding and managing risk is essential to strike the appropriate balance of security while accommodating innovative research.

In addition to supporting the NCRIS sector, these activities will create convenient on-ramps for other institutions and organisations, including small-to-medium enterprises, to engage, driving wider coordination and a more unified approach to the constantly evolving challenges and threats.

³⁵ Australasian Higher Education Cybersecurity Service (AHECS), 'AHECS'. [website], (2024). < <https://www.ahecs.edu.au/> > accessed 09 Jan 2024.

³⁶ Department of Home Affairs, Australian Government, '2023-2030 Australian Cyber Security Strategy'. [website], (22 Nov 2023). Department of Home Affairs Website, < <https://www.homeaffairs.gov.au/about-us/our-portfolios/cyber-security/strategy/2023-2030-australian-cyber-security-strategy> > accessed 09 Jan 2024.

³⁷ Australian Bureau of Statistics (ABS), 'Five Safes Framework'. [website] (08 Nov 2021). Australian Bureau of Statistics, < <https://www.abs.gov.au/about/data-services/data-confidentiality-guide/five-safes-framework> > accessed 09 Jan 2024.

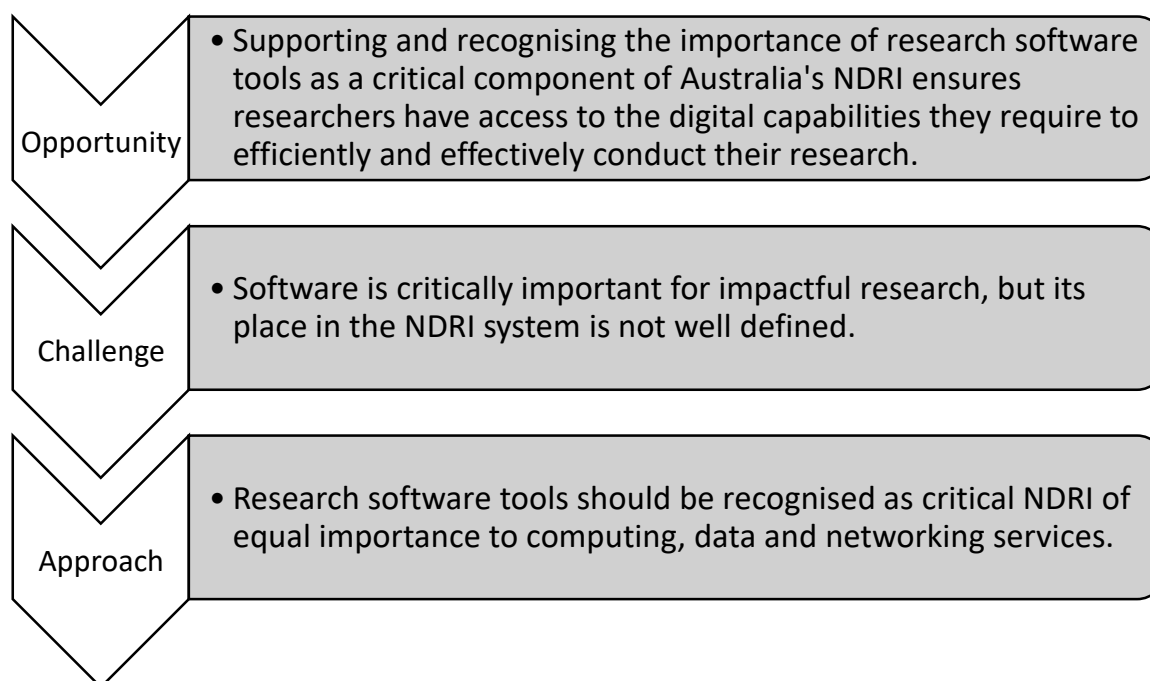
³⁸ Office of the National Data Commissioner, 'Data Availability and Transparency Act 2022'. [website] (1 Apr 2022). < <https://www.datacommissioner.gov.au/law/dat-act> > accessed 09 Jan 2024.

³⁹ Department of Education, Australian Government, 'Guidelines to Counter Foreign Interference in the Australian University Sector'. [website], (17 Nov 2021). Department of Education, < <https://www.education.gov.au/guidelines-counter-foreign-interference-australian-university-sector> > accessed 09 Jan 2024.

⁴⁰ The Australian Signals Directorate, Australian Government, 'Information Security Manual (ISM) | Cyber.gov.au'. [website], < <https://www.cyber.gov.au/resources-business-and-government/essential-cyber-security/ism> > accessed 09 Jan 2024.



6. Maximised by openly available research software tools



Opportunity – Supporting and recognising the importance of research software tools as a critical component of Australia's NDRI ensures researchers have access to the digital capabilities they require to conduct their research efficiently and effectively.

National-level support will enhance the ability of Australia's NDRI to create, house, operate, and provide research software tools to all users while also nurturing the careers of NDRI's research software engineers. Recognising the importance of research software will augment the ability of software creators to develop and validate their work, amplify the reach of collaborative efforts, and ensure that the diverse needs of research software users can be better addressed.

An NCRIS Case Study

The Australian Community Climate and Earth System Simulator (ACCESS-NRI) has released two new workflows for the Earth System Model Evaluation Tool (ESMValTool) and the International Land Benchmarking (ILAMB) tools⁴¹. These model evaluation tools allow researchers to compare and evaluate different Earth-system models, which is essential to test their accuracy and understand comparisons against other models. Both tools are developed by an international community of researchers and research software engineers. ACCESS-NRI is joining those efforts and releasing configurations and workflows for those tools to be used by the ACCESS community at NCI. These two workflows are specifically designed to connect the ACCESS modelling outputs to the wealth of data available at NCI for the benefit of the broader Australian research community.

Challenge – Software is critically important for impactful research, but its place in the NDRI system is not well defined.

⁴¹ The Australian Earth-System Simulator (ACCESS-NRI), 'ACCESS-NRI Releases Two Model Evaluation Workflows for the ESMValTool and ILAMB Tools', ACCESS-NRI [website] (23 Nov 2023) < <https://www.access-nri.org.au/access-nri-releases-two-model-evaluation-workflows-for-the-esmvaltool-and-ilamb-tools/> > accessed 04 Jun 2024.



Software has become an essential component of modern research, enabling insights and collaborative practices that underpin scientific progress and innovation. However, its creation is often an invisible output of the research process. In the NDRI ecosystem, research software is an inextricable component of digitally supported activities, yet its position within this system is not well defined or acknowledged.

This Strategy identifies two different but related aspects of research software development, which require investment in:

- funding for research software development activities.
- funding infrastructure used for research software development.

Research software needs are as varied as the research domains and communities supported by NDRI. Access to professional research software developers differs across the sector, depending on research funding and university support systems. The software itself can take many forms, from simple single line commands to complex platforms linking multiple software packages together. All research software must be cybersecure by design. This includes the use of trust and identity services and frameworks as a foundational component.

Software engineering is a specialised field, and researchers may not have the ability to develop software for themselves, or reusable software that is able to be used by others. In some cases, software development requires both software expertise and a deep understanding of the needs of a research community, for example, climate or geoscience research. Although not all needs can be met by the NDRI system, it is important that there is support at the national level for some nationally significant research due to the scale and complexity of software demands. Maintaining the attractiveness of non-commercial research institutes to software developers and IT professionals in Australia is critical for the delivery of this outcome.

The rapid evolution of computing and data technologies compounds these problems, often leading to complex needs for coding portability and the curation of outdated research software. Other limitations to the use of research software include rules of use for commercial software, particularly on Tier-1 HPC or cloud compute and intellectual property (IP) considerations.

The diversity in user needs and the ‘invisibility’ of software results in software developers and researchers needing to create custom software solutions that take significant time and effort to maintain. The need for researchers to reprogram code to use HPC capabilities has been flagged as an inefficient use of time and resources. NDRI has an important role to play in supporting the maintenance and availability of software to maximise the impact and value of NDRI services.

Approach – Research software tools should be recognised as critical NDRI of equal importance to computing, data, and networking services.

As with computing and data, the NDRI system cannot support all researcher software demands, however, it should enable dedicated software engineering support (on a priority basis) for large scale and complex projects of national significance both domestically and within the broader global research software ecosystem. An example of such a project is the ACCESS-NRI NCRIS facility. NDRI support should be provided for the maintenance and curation of critical software that is needed to ensure access and usage of significant digital assets. Software engineering capabilities should also be based on best practice and integrate security, including trust and identity frameworks, at each phase



of the development cycle. This could also include version control and digital preservation measures. In addition to supporting the development and maintenance of research software, NDRI can also facilitate the broader Australian research communities in training and accessing suites of already available, configured, and connected software, for example, by providing local configuration and portability on relevant Australian computational platforms. Due to the scale of demand, software effort should be deployed where it has the most impact, in relation to NCRIS, a pre-processing workflow alongside an instrument that will benefit all users of that instrument.

To ensure research software is recognised as critical NDRI, it must be visible and shaped for wider reuse, while critical research software infrastructure, alongside research software engineers, must be sustained (as detailed in the National Agenda for Research Software⁴²). NDRI should support strategies that enable this three-pronged approach to improve software availability for researchers (of various skill levels), while also supporting up to date software repositories and ensuring that software tools are meeting diverse community needs. Providers of software tools should also be guided by the principles described in the UNESCO Recommendation on Open Science. Making software as openly accessible as possible, while aligning with the interests of the global research software ecosystem, will enable its reuse, reducing duplication of work and optimising software usage. This will maximise the societal value derived from the broader NDRI investment.

Implementation and Review

Implementation

This Strategy should be complemented by the development of an NDRI Investment Plan, funded and implemented through NCRIS. The Investment Plan should keep at its core the concept of a user-centric plan, identify the NDRI expected to be needed in 5-10 years by research communities, and other users, address critical questions, and build an integrated suite of NDRI to support those communities.

An NDRI Working Group will be established to develop the NDRI Investment Plan. The group will be comprised of eminent people and leaders who possess field-specific expertise drawn directly from Australia's NDRI landscape. This investment planning process will be a facilitated process that is guided by a publicly available ToR. The Working Group ToR will promote close collaboration and shared planning among stakeholders alongside their wider networks. It should be clear on:

- priority research questions and the associated research communities.
- the underpinning/research sector wide NDRI needs to be addressed.
- the research question/community specific NDRI needs to be addressed.
- how the Investment Plan enables research communities to be supported as their NDRI needs develop, including building existing leadership, governance, and policy activities within the current NDRI network into a coordinated response with shared strategic intent.
- how new NDRI investments will build on existing investments, and links to complementary NDRI or other initiatives.

⁴² The Australian Research Data Commons (ARDC), 'Developing a Research Software Agenda for Australia | ARDC'. [website] (2022), ARDC, < <https://ardc.edu.au/project/research-software-agenda-for-australia/> > accessed 09 Jan 2024.



The Investment Plan should be submitted to the Australian Government for consideration by the end of (calendar) 2024.

The Government should also use this Strategy to catalyse broader conversations about establishing a national approach to digital research and innovation across government, academia, and industry. Development of Australia's NDRI ecosystem must include measurable engagement with First Nations peoples and acknowledgement of the value First Nations knowledges can offer this process.

This Strategy complements other government digital strategies, including (but not limited to) the Australian National Data Integration Infrastructure (ANDII) system⁴³, DATA, the Digital Health Blueprint and Action Plan 2023-2030⁴⁴, the 2023-2030 Australian Cyber Security Strategy, the National Framework for the Assurance of Artificial Intelligence in Government⁴⁵ and the Data and Digital Government Strategy⁴⁶, which aim to maximise access and use of data assets by the government, research and innovation sectors.

Monitoring and Review

The Strategy will be monitored by the NRIAG in line with its ToR, which include reviewing current NRI facilities.

The need for a stand-alone NDRI Strategy will be reviewed in the context of the development of the next NRI Roadmap, expected to be published in 2026.

⁴³ Australian Bureau of Statistics (ABS), The Australian Institute Of Health And Welfare (AIHW), 'National Disability Data Asset'. [website], Australian Bureau of Statistics, < <https://www.abs.gov.au/about/data-services/data-integration/integrated-data/national-disability-data-asset> > accessed 09 Jan 2024.

⁴⁴ Department of Health and Aged Care, Australian Government, 'The Digital Health Blueprint 2023–2033'. [website] (21 Dec 2023). Australian Government Department of Health and Aged Care, < <https://www.health.gov.au/news/the-digital-health-blueprint-has-been-published> > accessed 09 Jan 2024.

⁴⁵ Department of Finance, Australian Government, 'National Framework for the Assurance of Artificial Intelligence in Government' < <https://www.finance.gov.au/government/public-data/data-and-digital-ministers-meeting/national-framework-assurance-artificial-intelligence-government> > accessed 04 Jul 2024.

⁴⁶ Australian Government, 'The Data and Digital Government Strategy'. [website] (May 2023). Data and Digital, < <https://www.dataanddigital.gov.au/> > accessed 09 Jan 2024.

