Submission
2016 National Research Infrastructure Roadmap
Capability Issues Paper

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Questions

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

An issue of particular concern for Australia is that of the falling success rate of mineral exploration and the consequent withdrawal of international exploration funding from Australia. This is because the near-surface easy finds of economically viable mineral deposits have already been made and because more than three quarters of Australia is under post-mineralisation cover. This makes mineral exploration extremely difficult with our current approach to exploration and our current knowledge of how the Australian continent was built, of how and where mineral-bearing fluids moved through the ancient crust, and of the conditions that caused those fluids to precipitate out massive deposits of valuable minerals.

We are currently living on the exploration finds of the past century, but those mines are rapidly being depleted and we are not replacing our inventory with new ones. The opportunity cost of not preparing for future minerals development is high. Resources account for 59 per cent of Australia's exports and the outlook for our iron ore, coal and base metals is strong. [1] While steel and energy consumption in emerging economies will continue to increase, there will be new growth for copper, aluminium and a range of other minerals and metals that are essential inputs for sophsticated consumer goods. Moreover, mining outputs are indispensable for the production of renewable energy technologies, so if the government wishes to expand the share of renewables in the economy, this will require much more mining, including of non-bulk minerals that are under cover. [2]

For example, the United States Geological Survey found that a typical land-based wind turbine comprises 89.1 per cent steel, 5.8 per cent fiberglass, 1.6 per cent copper, 1.3 per cent concrete, 0.8 per cent aluminium and 0.4 per cent other materials.[3] To produce this steel and concrete, more than 220 tonnes of metallurgical and thermal coal are required for each turbine installed. More steel – and therefore more iron ore and metallurgical coal – is required for transmission infrastructure.[4]

[1] See Reserve Bank of Australia, International Trade and Balance of Payments statistics, Table I1; Department of Industry, Innovation and Science, Resources and Energy Quarterly – March Quarter 2016, released on 8 April 2016, Canberra, p. 24f.
[2] See, for example, David R. Wilburn, *Wind energy in the United States and materials required for the land-based wind turbine industry from 2010 through 2030*, Scientific Investigations Report 2011–5036, US Department of the Interior, US Geological Survey, 2011, p. 7; Goksin Kavlak *et al.*, *Metals Production Requirements for Rapid Photovoltaics Deployment*, an MIT Future of Solar Energy Study working paper, 2 July 2015, p. 2
[3] David R. Wilburn, *Wind energy in the United States and materials required for the land-based wind turbine industry from 2010 through 2030*, Scientific Investigations Report 2011–5036, US Department of the Interior, US Geological Survey, 2011, p. 7
[4] Minerals Council of Australia estimate based on David R. Wilburn, op. cit., and World Coal Association, *Coal and Cement*, viewed on 1 April 2016.

Similarly, a study from the Massachusetts Institute of Technology explains that existing solar photovoltaic (PV) technologies embody materials derived from metals or metal by-products, including silicon for crystalline silicon, tellurium for cadmium telluride, and indium, gallium and selenium in copper indium gallium diselenide.[5] The authors add that: 'providing a high proportion of the total electricity through PV would require energy storage technologies that would also entail material requirements'.[6]

Australia has an abundance of these economy-sustaining minerals hidden in the covered areas and we need to develop the new geoscience knowledge and technologies necessary to lift the success rate of exploration, in the three-quarters of Australia that is covered, to the level that we enjoyed 30 years ago in the uncovered areas. If we do not achieve this in the near future then Australia will not only be unable to export these minerals to the rest of the world but will actually have to import them to provide for its own needs - a serious reversal of the historic situation that has supported our economy.

UNCOVER is an initiative, under the aegis of the Australian Academy of Science, created specifically to address this issue through carefully targeted data acquisition and research programs. It is at the core of the National Mineral Exploration Strategy (https://scer.govspace.gov.au/files/2012/12/National-Mineral-Exploration-Strategy.pdf) released by COAG. It is a partnership of the Australian exploration industry, government agencies including all of the State Geological Surveys, Geoscience Australia and the CSIRO, academic institutions and NGOs (see http://www.uncoverminerals.org.au/ for more information). While addressing this issue UNCOVER will also generate significant knowledge that will help in all aspects (groundwater, for example) of human interaction with the solid earth.

AMIRA International in collaboration with UNCOVER, industry, suppliers, research organisations, government agencies and other key stakeholders is developing a comprehensive Roadmap of the data and research programmes required and the infrastructure necessary to support this endeavour. Stage 1 of the roadmap is available at http://www.uncoverminerals.org.au/documents/amira-uncover-roadmap and Stage 2 of the roadmap will be delivered in the second quarter of 2017. This should be an important document in the development of the nation's research needs and the national research infrastructure needs.

In terms of National Research Infrastructure, UNCOVER will be particularly dependent upon AuScope. It will also be heavily dependent upon high-performance data and computational capability and on advanced data analytics for extracting information from sparse data sets (see also Question 23).

The new capability that UNCOVER will need of AuScope relates mainly to the creation of data sets that form critical infrastructure to support not only the research needed for UNCOVER but also for understanding appropriate management of our nation's sedimentary basins (for groundwater, for new energy systems such as unconventional gas, and for waste storage) as well as the underlying fundamental research that facilitates our understanding of how the earth works and how it supports life and human society. The basic need is for an integrated network of geophysical and remote

[5] Goksin Kavlak *et al.*, *Metals Production Requirements for Rapid Photovoltaics Deployment*, an MIT Future of Solar Energy Study working paper, 2 July 2015, p. 2.
[6] ibid., p. 2.

sensors and geochemical sampling and analysis together with ongoing development of the global positioning system.

One of the most significant recent scientific advances in the field of economic geology has been the recognition that mineralisation is a highly punctuated process, occurring (often over wide areas, and manifesting as many different styles) within relatively narrow time windows in the geological history of their host terranes. This advance has occurred at the same time as the mineral systems approach to exploration targeting has emerged. The mineral systems concept sees individual mineral deposits as components of much larger geological systems and considers that if we can define and characterise the overall nature of the system, we can develop a framework to spatially target new mineral deposits. Currently, a major barrier to the definition of these mineral systems is the difficulty in relating particular minor mineral occurrences to a particular mineral system - in many cases there is significant ambiguity. If we knew the age of these occurrences, we would know with some confidence the broad metallogenic event they related to and therefore would be able to use their spatial distribution to build our understanding of the spatial characteristics of that particular mineral system. This in turn would provide a major benefit to our ability to develop targeting models. Therefore, a program that is focused on providing as much geochronological data as possible for mineral occurrences (not just major deposits) would be of immense strategic value to the mineral exploration industry and would constitute a significant infrastructure for government agencies and academic research.

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

A national research infrastructure should be designed to underpin and facilitate a nimble, agile and cost-effective national research capability able to address the changes, demands, and challenges the future will present. This is best achieved by ensuring that the individual facilities form an interactive ecosystem of capability. Hence the governance models needs to include consideration of effective measures for interacting with other facilities. Although AuScope has been effective at this it is probably also worth considering the creation of an overarching Council made up of senior governance/management from within each area to achieve greater coordination.

Generally speaking one of the most effective governance model has, like AuScope, been a not-for-profit organisation with an independent board and outstanding leadership ability at the Chief Executive level. This allows for independence from institutional politics and facilitates strategic decision-making for the benefit of the entire community.

Co-investment in national research infrastructure requires special consideration in the governance structure. It should be clear that co-investment is vital to the success of the programme and is required. There should be a minimum requirement for co-investment but no upper limit. To avoid distortion of the purpose of an infrastructure facility, co-investment should only be accepted if it is appropriate to the goal of the facility and if it will be effective in achieving the desired outcomes. Co-investment from the States and Territories is a particularly important requirement. Thus it is important to be flexible about arrangements and timing (particularly with regard to flexible lead times) to enable development of a framework for collaborative investment with States and Territories despite the intermittent nature and different funding cycles of their investment programs in research infrastructure. This has proven important for AuScope and therefore for the Earth Sciences, and for the UNCOVER initiative.

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

From the perspective of the UNCOVER initiative, Australia provides an exemplar for most of the problems that need to be solved. Furthermore, Australia has the skill set needed to lead the world in this area and through AuScope and associated CRCs is developing world-leading technology. Hence we would not at this time prioritise access to international facilities over development of national capability. Obviously this is not to preclude the building of effective partnerships with overseas expertise and capability.

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

Clearly it is not the responsibility of a national research infrastructure system to usurp the role of universities and the ARC in educating the nation's research workforce and the scientific technical workforce.

However, it is inevitable (and this has already happened and is happening) that the specific, high-level operational skills required by the workforce within the infrastructure facilities become significantly improved and sharpened with experience in providing the research workforce with access to the infrastructure capability.

A paradigm shift that occurred with the implementation of the NCRIS model, and a significant contributor to its success, was the provision of high-quality staff (both technical and scientific) within the infrastructure facilities to lower the intellectual cost of effective access to the available capability. This has meant that AuScope and other infrastructure facilities have actually been involved in driving innovation out in the research world and in significantly raising the skill level of the research workforce in accessing and using infrastructure capability to its maximum effectiveness. This is probably the most effective way of improving this aspect of the research workforce skills because it is being driven by those who, on a daily basis, are intimately involved with the infrastructure and its evolution in capability.

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

See answer to Question 5.

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

See answer to Question 5.

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

Access should broadly follow existing NCRIS guidelines - access for little or no cost to meritorious research (merit to be determined externally and independently), data made widely and freely available as soon as possible, industry access with appropriate cost recovery but with guidelines in place to ensure that this does not compete unfairly with Australian commercial providers to industry.

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

At this stage the infrastructure provided by AuScope to the Earth Sciences in general and to the national effort under the UNCOVER initiative is critical to ongoing success. It underpins research of the highest quality at the international and it underpins research that is central to activities that support the national economy. Hence at this stage we would recommend against any consideration of decommissioning.

Under the current arrangements, the liabilities and risks for hosting institutions associated with formal decommissioning of NCRIS infrastructure is already impeding the potential for future collaboration with new or existing partners. Hence formal policies and conditions for the decommissioning (including responsibility for and ownership of equipment and funding for wind-down costs) of a particular facility need to be in place at the beginning to provide clarity for a hosting institution.

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

There is clear evidence from many studies around the world that long-term, strategic funding provides far greater return for investment than short-term ad hoc funding.

Funding bodies such as the ARC should be encouraged to support the NCRIS facilities and there should be sufficient funding in their grants for infrastructure access.

The best approach would seem to be a statutory fund. An annual subvention of a fixed proportion of the capital outlays could be provisioned to support efficient and effective use of the research infrastructure. This would fund expert staff to drive the infrastructure and provide the security of tenure over the planned life of the infrastructure that is necessary to ensure the outcome identified in the previous paragraph. It could also fund the running costs of the infrastructure.

According to the ABS, the Australian Government spends over $9 billion a year on what is referred to as "science". NCRIS was funded by the Australian government as a $500 million program over five years. Considering the enormous positive impact that this infrastructure system has had on the nation's research capability, consideration should be given to whether this is an appropriate balance of funding or whether it would be more effective to increase the proportion spent on underpinning infrastructure.

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

Whenever that would improve quality and consistency and whenever it would provide a better interface with industry clients.

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?

See Question 21.

Advanced Physics, Chemistry, Mathematics and Materials

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?

The reduction in cost, portability and sensitivity of the next generation of earth monitoring and imaging sensors will facilitate a revolution in the way we can image and monitor the earth's crust and the nature of what lies beneath us. Australia needs to develop an integrated distributed network of geophysical and remote sensor deployments and geochemical sampling and analysis that will enable research into: the current state of the earth (stress, groundwater movement, human impacts, natural hazards); the processes leading to its formation (mantle process, crustal architecture, plate tectonics); and more efficient discovery and use of earth-bound resources (UNCOVER, mineral and energy systems, unconventional gas, waste storage and geothermal – extending the AusDEEP concept regionally).

Nationally and internationally significant open-file datasets produced by these deployments will provide the currently missing links between solid earth geophysics and geoscience, geodesy and geospatial analysis of the earth's response to natural and human activity, mineral and energy system science, groundwater mapping and modelling and links to agricultural, biological, ocean and climate science research and monitoring systems. It will facilitate integrative science that will have direct impact within government and industry and will provide datasets that will underpin informed policy development by allowing monitoring of human impacts on the earth and its systems.

These datasets, and related simulation models utilising existing and new technologies that consume the data, will provide 3D and 4D models of the Australian crust and facilitate prediction of natural and human induced changes on a variety of temporal and length scales.

This would make Australia the most efficiently utilised continent on earth.

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?

Considering the impact for the nation, the Earth Sciences are significantly underrepresented. Research in the solid earth sciences provides the knowledge for the interaction between human society and the planet on which it lives and it underpins Australia's resources industry, which in 2014 constituted 59% of all Australia's exports and about 10% of GDP. In terms of publications/citations, the geosciences are the highest impact of any science in Australia per researcher.

The Earth Sciences would be better represented, and much more effectively so for the benefit of the nation, if they were included in STEM as has been the case in the recent past.

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?

The development of translational data science is a burgeoning area for mathematics and high-performance computing. The cost of mapping Australia with new technologies at standard survey scale (the data being fundamental infrastructure for industry, government, and academia) is massive but it will be possible to extract similar (and perhaps better) information with far less data if the data is acquired incrementally in a manner that is guided through extremely smart data analytics. Hence, both from the point of view of developing fantastic new data analytic technologies for extracting information (including robust understanding of uncertainties) from sparse datasets and massively reducing data acquisition costs while chasing a trillion dollar prize, UNCOVER/AuScope is the ideal laboratory.

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?

The design of the NCRIS system with its interlocked ecosystem of capability has, in effect, converted a range of activities, such as geospatial, characterisation, fabrication, and 'Omics into underpinning capabilities for other NCRIS facilities and for the national research system as a whole. Whilst this should be recognised as providing enormous value to Australia it should also be recognised that these capabilities are best developed in their natural homes (AuScope, AMMRF, Fabrication, BPA) rather than being abstracted, as major components of eResearch have been.

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.

Simply providing equipment to individual disciplines will not provide an effective national research infrastructure system. This can only be achieved by designing and creating an integrated ecosystem of facilities that provides, to all researchers with meritorious programs, effective access to underpinning, enabling capability.

Apart from the obvious need for AuScope, the Earth Sciences and the UNCOVER initiative benefit enormously through integrated access to Characterisation, Fabrication, and all of the underpinning capability in eResearch, data management and high-performance computing.

Such a system can only be considered successful as a national research infrastructure if it underpins and facilitates a nimble, agile and cost-effective national research capability that is able to address the changes, demands, and challenges that the future will present and if it is able to support those research challenges regardless of whether they present through the University, government agency, military, or industry research communities.

The NCRIS model has had an enormously beneficial impact upon Australia's national research capability. However, its biggest problem was that it operated within a weak strategic environment. Even though the funding through EIF and Super Science was critical for its survival, several important aspects of the NCRIS model were diluted in those funding schemes because of their origins. NCRIS (and, therefore, the national research infrastructure system itself) has been damaged through recent uncertainty of funding.

The NCRIS model has also suffered because of the absence of an ongoing strong, formal committee of experts (such as the NCRIS committee itself) championing the needs of a national research infrastructure system and providing ongoing advice to government, overarching strategy to the program, consolidated feedback to educational and training institutions, maintenance of appropriate balance of assigned priorities, and coherent system-based decisions about issues such as decommissioning. Consideration should be given to the permanent creation of such a body.