AN ORGANISATION FOR A NATIONAL
EARTH SCIENCE INFRASTRUCTURE PROGRAM

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Cover Letter for AuScope's submission to the National Research Infrastructure Roadmap Capability Issues Paper

Members of the National Research Infrastructure Review Committee,

Australia is a vast and complex continent. It contains some of the world's oldest rocks, and some of the youngest. It has regions that have been undisturbed for billions of years while at the same time the margins of our plate are actively deformed as they are subducted beneath our neighbours.

The Earth holds the clues that allow us to understand how our planet works, how the solar system was born, how life evolved, and how our dynamic planet continues to change. The Australian crust hosts some of the richest mineral and energy systems on the planet (currently contributing approximately 10% of Australian GDP and >50% of exports) and has been the foundation on which our economy was built. Our economy will continue to grow and provide jobs for hundreds of thousands of Australians over the next decade based on the resources the Australian crust provides us.

In order to ensure the stability and growth of industry two critical challenges need to be addressed by the geoscience community. Firstly, we need a more effective method of exploring for minerals under areas of sedimentary cover and, secondly, we need to sustainably manage competing demands for energy and water resources in Australia's sedimentary basins.

Exploration under cover

From an exploration perspective Australia is, quite incorrectly, considered a mature region. The "easy" mineral deposit discoveries that have some expression in the rocks exposed at the surface, have mostly been identified. However, the Australian crust has only given up the smallest of its secret mineral potential. The vast majority of our mineralised provinces remain largely unexplored due to the fact that they are buried beneath younger sediments, which obscures them from discovery with our current exploration capability.

Our ability to understand the nature of these cover sequences, developed as layers over geological time, and what they inform us about the crystalline rock beneath, is one of the critical scientific challenges of the coming decade. Key to the sustainability of the minerals industry as an underpinning economic pillar in Australia will be the development of new sensor technologies, the acquisition of national high-resolution geophysical and geochemical datasets, and the development of eResearch tools that will allow us to intelligently analyse and process the deluge of observational data that is beginning to be collected.

The UNCOVER initiative is an industry led research program designed to address these issues. This initiative brings together researchers from industry, government and academia. It recognises the value of existing AuScope and Geoscience Australia programs like large-scale geophysical instrument deployments, national drilling and sampling programs and, the acquisition of 3D geochemical and geochronological profiles for the entire country. These new national datasets and the latest transformational data analysis tools, that include machine-learning and Bayesian approaches to big data integration, will revolutionise the way mineral exploration is undertaken in Australia over the next 25 years.

Sustainable basin management

The emergence of new ways to extract energy resources from our sedimentary basins (shale gas, coal seam gas, geothermal) coupled with the development of alternate uses for subsurface reservoirs (compressed air storage, waste storage, geosequestration) and an ever increasing demand for fresh water puts more, and increasing, pressure on our sedimentary basins than ever before. Resource sterilisation, groundwater contamination, surface subsidence, salinity and human induced seismicity are just some of the risks Australia faces if poor or ill-informed management policies relating to these basin bound resources are implemented.

The problematic complexity surrounding resource management is compounded by the historic practice of collecting data to support exploration for energy resources in basin environments. This practice traditionally focussed only on the data relevant to a specific commodity or part of the basin that may contain it. However, a recent paradigm shift has seen resource managers starting to consider the pore-space of the crust as the resource of value, rather than whatever fluid it may contain. This has fundamentally changed the way that we think about basins as a source of sustainable resources. In order to make this new paradigm shift a reality, a new generation of geoscience data is needed. Data, allowing earth scientists to constrain the geometry of entire basins and the aquifer systems within them, along with more complete geochemical datasets and deployments of surface based monitoring systems that allow the tracking of earthquake activity, groundwater flow, surface movements and build up of stress, is critical for the future health of these complex geological formations.

The capture of this new data will allow the behaviour of entire basins, in response to natural and human induced change, to be constrained and accurately predicted.

The investment opportunity

Australia's Earth and geospatial science research has reached a tipping point. The size and remote nature of our landmass, combined with our ability to measure and sample, only the shallowest portions of the crust, has made Australian researchers expert at the efficient use of sparse datasets.

However, the reduction in cost to produce the next generation of Earth monitoring and imaging sensors combined with increased portability and sensitivity, will, facilitate a revolution in the way we can image and monitor the Earth's crust and create a new understanding of the nature of what lies beneath our feet. The deployment of grids of multi-sensors in boreholes or surface based locations will facilitate the development of datasets that will be enable research into:

(1) the current state of the Earth (stress, groundwater movement, human impacts, natural hazards),

(2) the processes leading to its formation (mantle process, crustal architecture, plate tectonics), and,

(3) more efficient discovery and use of earth-bound resources (UNCOVER, mineral and energy systems).

AuScope's Australian Earth Observing System is a distributed sensor system, a *10 Million Square Kilometre Array*, that will allow us to make Australia the most intensively monitored, deeply imaged, best understood and most efficiently utilised continent on Earth.

It is fortunate that the infrastructure requirements associated with large scale distributed sensor deployments to facilitate significant advances in both exploration under cover and, the sustainable management of our basins are remarkably similar. Both need access to:

- large fleets of a variety of state of the art, field deployable geophysical instruments,
- access to existing or new boreholes for in-situ sampling and subsurface sensor deployment,
- the development of new workflows and observation techniques, including the use of miniaturised sensors and drones, to revolutionise the speed and fidelity of geophysical imaging programs,
- ongoing time-series observational monitoring to build up models of the architecture and composition of the deep Earth, baseline data for monitoring changes to the crust and assessment of potential for associated geo-risks,
- robust data infrastructure for transfer, discovery and storage of large datasets, telemetered time-series data and geospatial data,
- Simulation and modelling codes that can utilise this data to develop national Earth models (analogous to the ACCESS models in the climate science community), and,
- access to eResearch tools and High Performance Computing (HPC) and related storage to allow these very large and complex datasets to be interrogated and modelled.

AuScope and the Australian Earth Observing System

The AuScope Infrastructure Program has been a collaboration between Australian and State research institutions in universities and government, with funding support from the Australian Government's National Collaborative Research Infrastructure Strategy (NCRIS). A 'world class research infrastructure to characterise the structure and evolution of the Australian continent in a global context from surface to core in space and time' has been our vision.

Since its inception in 2006 AuScope has served the Australian Earth and Geospatial communities through the development of the *AuScope Earth Model*. This is an integrated observing system that involves geophysical, petrophysical and geospatial facilities serviced by a robust Grid based eResearch infrastructure, virtual laboratories and simulation and modelling tools. It is upon this foundation that the

Australian Earth Observing System will be built.

A recently completed Impact Assessment Study, undertaken by Lateral Economics, assessed the economic impact of the development of the existing AuScope infrastructure for Australia. This study identified a variety of direct and indirect user groups of AuScope-related outputs incorporating:

- individual researchers in universities or structured research collaborations (e.g. cooperative research centres, specialist research groups or facilities, industry partnerships) with clear examples across the breadth of AuScope's ten partner universities and beyond,
- State and Territory geological surveys (geoscience agencies) and Geoscience Australia with relative activity and usage skewed towards those jurisdictions with greater size and scope of geological survey work, notably Western Australia and Queensland, and,
- individuals or firms that utilise data or analysis and interpretation produced by the above groups (e.g. mineral or energy exploration firms, natural resource managers).

The research and other benefits resulting from AuScope-related physical and data infrastructure is equally diverse. Key areas of impact influenced by AuScope, each of which are reasonably distinct, include:

- fundamental Earth science,
- resource exploration,
- spatially sensitive industries, and,
- natural and built environment.

Based on an initial investment of $41.4 million, the indicative economic assessment suggests a net benefit to Australia from AuScope between $2.3 billion to $6.2 billion – with our best estimate of $3.7 billion (net present value in 2015-16 terms, over the period to 2040-41).

A net benefit of $3.7 billion is equivalent to $15 of benefit for every $1 in economic cost – a substantial return on investment. While substantial, the scale of these estimates is consistent with other economic assessments of similar initiatives, in Australia and the United States.

Planning for the AEOS

In 2011 AuScope undertook a community wide engagement exercise to develop a future plan should new capital investment become available. This resulted in the development of the AEOS concept and a series of projects were developed and costed at a variety of activity levels.

These are presented in the AuScope Earth Observatory Roadmap document - http://www.auscope.org.au/wp-content/uploads/2015/11/AEO_AuScope_Nov_2011.pdf.h A second updated roadmap was produced in 2015 which further refined the Australian Earth Observatory concept and incorporated the requirements of the fledgling UNCOVER and Sustainable Basin Management initiatives - http://www.auscope.org.au/wp-content/uploads/2016/09/AEOS_Strategic_Overview_2015.pdf.

The full quantum of funding required to support the infrastructure requirements of AuScope's research initiatives will need to be assessed in the future particularly in light of the recent progress made by partner organisations in the detailed planning of their future research programs. However, based on previous costings, and calculated at a minimum and full level of support, the quantum is likely to be between $10 to $20 million per year for a 10 year program.

We hope that this information, and the specific responses to the questions related to the issues paper that follow, help with the panel's review of research infrastructure requirements in Australia. Also attached is the Executive Summary from Lateral Economics' Impact Assessment (mentioned briefly above), a brief document outlining key science questions that will drive the AEOS and brief description of some of the programs that will support that science.

If you have any questions regarding this submission, please contact me for clarification. I would end this submission with a word of appreciation, on behalf of Australia's Earth and Geospatial research community to the Australian Government and the Office of the Chief Scientist, for undertaking what we regard as a critical step to secure a brighter more sustainable future for our continent and its people.

Regards

Dr Tim Rawling
CEO AuScope Limited

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?

Pressing social issues and critical economic drivers over the next decade will see unprecedented demands placed on the Solid Earth and Geospatial Science communities in Australia and on the research infrastructure that supports their endeavor. We will see a heightened need for new mineral discoveries in more difficult exploration environments and the development of nascent clean energy and geological waste storage technologies. Food, water and environmental security will become a more pressing issue as we place more demands on the "geological services" provided to us by the shallow crust and particularly in the context of accelerating climate and environmental changes.

Whilst the Solid Earth Sciences are considered in the National Research Infrastructure Review Issues Paper they are only discussed briefly in the Environment and Resource Management section. This approach undervalues the research impact that geosciences have internationally as well as the importance of the resources and energy industry to the Australian economy.

The geosciences are an integrative science, which through geophysics, geochemistry, geodesy and observational geology provide a connection between the traditional STEM sciences and the Environment and Resource Management sectors. Whist it is appropriate to consider part of the Solid Earth Geosciences in the Environment and Resource Management capability area, the grouping does not capture the full scope of the pure or applied research being undertaken in the field.

Consistently ranked as the most internationally competitive of Australian research disciplines, the Australian Earth science research community is well credentialed to contribute to a deeper understanding of the Earth system and its behaviour.

The past success of the Australian Earth science effort can be attributed to a variety of factors. With a whole continent to study, Australian Earth scientists are blessed with a remarkable natural laboratory. With an economy underpinned by a strong focus on mineral and rural production, there are strong economic incentives for Earth science research.

Of critical importance to the Earth science's success has been access to high quality infrastructure. As with all sciences the development of instrumentation and computation tools goes hand-in-hand with leading research. More often than not it is advances in the tools we use that render the intractable problems of yesterday solvable today. Australian Earth scientists have a proud tradition of development of new tools that have lead to fundamental breakthroughs in our scientific understanding. Examples include the SHRIMP ion probe and SyNROC at ANU and ANSTO, and the FAlCON airborne gravity gradiometer at BHP.

The mineral exploration industry, government geological survey organisations and academia have recently collaborated to develop the UNCOVER research initiative. This collaboration is likely to produce a decade-long research program funded from a variety of sources that will have significant research infrastructure requirements ranging from drill-hole access, development and deployment of new monitoring and imaging sensors, national-scale data acquisition collation and delivery programs, specialised data modelling, analytics, discover and machine learning algorithm development.

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

AuScope was established as a not-for profit company with an independent board. This is a model that has worked very well for us as it provides independence from institutional politics, allows for the development of truly national infrastructure and facilitates strategic decision making for the benefit of the entire community.

AuScope has also formed industry and/or science advisory panels, to provide advice to the CEO and the Board. Again this approach has worked very well for us and we feel that it has greatly enhanced our community engagement and has been valuable in making specific investment decisions where specific sectorial knowledge is critical.

AuScope required that independent access committees also be established to assess meritorious access for use of our infrastructure and facilities. These committees may contain members from the AuScope community but dominantly include researchers with no direct relationship with AuScope. An excellent example of how these committees have worked in our sector is the establishment of ANSIR which manages access to geophysical equipment pools but also provides strategic advice regarding community infrastructure requirements. See http://ansir.org.au for more details.

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

Where the case cannot be made for the development of an Australian infrastructure capacity, but there are international facilities that can be accessed then it is appropriate and prudent to fund access to the with research infrastructure funds.

Examples may include the International Ocean Discovery Program (IODP) membership or access to facilities such as CERN and international synchrotron facilities.

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

It is appropriate to consider access to international facilities where overall impact for Australian science does not justify the effort and investment of developing the capability here due either to the cost, scale or lack of broad community need.

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

Operational workforce *should* definitely be considered a research infrastructure issue but the funding of research-based staff and the undertaking of research utilising that infrastructure should not.

A skilled operational workforce is critical to ensuring that the infrastructure investment serves the research community effectively and provides the best long-term impact for the investment. This workforce can also facilitate the development of Significant National Datasets utilising the infrastructure when not undertaking specific research programs.

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

National research infrastructure should broadly follow existing NCRIS guidelines - access for little or no cost to Australian researchers, data made widely and freely available as soon as possible after collection, industry access with some cost recovery to support the infrastructure but with guidelines in place to ensure that research facility operation complies with competitive neutrality principles in relation to Australian commercial research or analysis providers.

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

Projects that have successfully evolved to the point where they can operate sustainably from external earnings, or which have transitioned from a primary research based usage to an operational or commercial status, could also be defunded but in these situations that financial saving can often be redistributed within the managing NCRIS capability to support the development of new related research capability.

Where defunding at the capability level is being considered the capability should be able to demonstrate broad research community support and ongoing usage for continued support. Where it is clear that: (a) there is no longer a use-case or community need for the capability, (b) new developments, technologies or practices have made the capability unviable and there is no clear path to return the capability to a position of effectiveness, or (c) where the capability has had poor governance and is functioning poorly as a result it may be appropriate to defund that capability.

Potential defunding decisions should involve research community consultation to ensure that this really is the best approach for that group.

In these circumstances it is critical that the de-funding is managed appropriately between the department and the capability and that decommissioning plans are put in place to transition skilled staff into other positions over reasonable timeframes.

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

The most critical aspect of any funding model is provision of financial certainty over time frames of 5-10 years. This allows for strategic planning and delivers far more significant financial return on the research infrastructure investment. Long term funding should be tied to the development of rolling 5-year business and 10-year strategic plans within the capabilities that are independently reviewed periodically as part of their performance management processes.

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?

The Earth and Geospatial Sciences are crucial to global challenges such as meeting growing demand for essential natural resources, mitigating the risk of catastrophic natural hazards, securing our energy wastes and understanding our potential to impact the functioning of our planet.

Meeting such challenges requires better understanding of how geological processes have shaped our planet and so distributed its resources and hazards. It requires more accurate information about the composition, structure and evolution of the Earth. It requires new understanding of the functioning of our planet and all its systems.

Addressing these priorities will require a more integrated research capability that provides for new ways to monitor and probe the planet. There is a need to integrate observations that extend from timescales of billions of years to the nanosecond, from the global scale to the atom, and from the top of the atmosphere to the core of the Earth.

The Australian Earth Observing System is proposed as an integrated research infrastructure capability to meet these needs. The observing system will deliver a new generation of accurate spatial and time-constrained data relevant to the evolution of our continent. Together with e-earth infrastructure it will support our capacity to model, analyse and simulate past, present and future processes within the Australian continent and its surrounding region.

In building on previous investments the observing system aspires to establish Australia as the most integrated and instrumented platform for continental observations in the world. It would do so through new geophysical instrument deployments that extend beyond our continent to the surrounding plate boundaries, deep ocean floors and to the deepest levels of the accessible crust. New data streams generated by such deployments will be supported by a new information management infrastructure together with expanded simulation and modelling capabilities.

This will create a geological telescope, that looks into the Earth not away from it. The Earth Science *Ten Million Square Kilometre Array* if you like! This very large research infrastructure investment will support research from applied mineral discovery, to new energy systems as well as the underlying fundamental research that facilitates our understanding of how the earth works and how it supports life and society.

Access to Australian or international Earth Science synchrotron beam-lines will extend the observational spectrum to real-time experiments at the nano-scale. Access to sub-surface experimental facilities at depths of up to five kilometres will provide a unique opportunity to unravel the physics of earthquakes, and learn how to deliver geothermal energy and safely secure energy wastes.

The provision of the required research infrastructure to support he development of an Australian Earth Observing System will help ensure that Australian Earth science remains at the forefront of the international science effort and continues to take the lead in solving the key challenges of our time. In so doing, it will ensure our Earth scientists are able to continue to provide extraordinary returns to Australian society.

Context for future research - Resources

Since the beginnings of the plate tectonic revolution some 50 years ago, global population growth and rising economic aspirations have created an unprecedented growth in demand for resources. The past 50 years have also coincided with massive Australian success in minerals and energy resource exploration, attributable in part to the new understanding provided by plate tectonics and new technology. Inevitably, maintaining a supply of resources will necessitate utilizing lower grade, less profitable resources, so productive mining will be dependent on development of much more efficient, much less energy-intensive approaches. Discovery of new resources will also require more accurate resource targeting, penetrating deeper into the crust than ever before. The challenges are significant. Success rates in exploration have been declining over the past 30 years, with exploration costs rising. But there is hope. Current estimates of Australia's mineral wealth are based on ready access to only 20% of the total prospective rock types. The challenge is to extend the search domain to the other 80% in the deeper hidden realms of the continent, obscured beneath surface veneers of sediment and regolith.

Some key strategic resources will be significantly depleted during this century and the services they provide will need to be replaced. The need for service substitution will see new technologies emerge that will, in turn, change the resource demand profile. In the 21st century we face a transformation of our energy systems, the beginnings of which we can see in the emerging low emission energy technologies. The vision of a new green economy is underpinned by technologies built on commodities such as lithium, indium, neodymium and other rare earth elements. With demand for these new energy commodities increasing rapidly, the new green economy is offering new opportunities to the resource sector, and for resource rich countries such as Australia, the opportunity to manage our resources to further secure prosperity for generations to come.

The UNCOVER initiative is an industry led research program that is addressing these issues. The initiative brings together researchers from industry, government and academia and recognises the value of large-scale geophysical instrument deployments, national drilling and sampling programs and the acquisition of 3D geochemical and geochronological profiles for the entire country, that build on existing AuScope and Geoscience Australia programs. New infrastructure investment in these national datasets and the latest transformational data analysis tools, including machine-learning and Bayesian approaches to big data integration, will revolutionise the way mineral exploration is undertaken in Australia over the next 25 years.

Context for future research - Energy and Waste

With one of the most energy and CO2-intensive economies and highest per capita energy footprints, Australia faces particular challenges in a carbon-constrained world. Understanding how to secure energy wastes on millennial timescales, through technologies such as CO2 capture and storage and nuclear waste storage is imperative. While there are many prospective sites for large-scale CO2 storage in our sedimentary basins, these basins are already being exploited for other purposes, or are being considered for new purposes. There is interest in understanding how to use our basins for geothermal power production. Of the alternative sources of baseload power, Australia has well recognised potential in enhanced geothermal power. However, we are yet to realize any significant production, at least in part because we have inadequate know-how of geothermal reservoir behaviour in Australia. The question of how we frame issues around, and regulate for, multipurpose basin management issues including waste storage is hampered by such fundamental geological uncertainties. In a world in which nuclear energy provides a potentially attractive option for providing low carbon electric power supply, the issues of nuclear proliferation remain a major disincentive. Furthermore, despite a global history of 60 years of power production, the issue of how best to safely secure high-level radioactive waste remains unresolved. Future growth in the sector will be determined in significant part by providing long-term secure geological storage of waste.

The AusDEEP facility will allow characterisation of basin response to human activities such as waste injection into deep aquifers at a fidelity that has never before been possible. The co-deployment of AEOS distributed earth imaging and monitoring sensors, at regional scale, will facilitated the interpolation of AusDEEP results throughout the entire basin and their application to other basin systems in Australia and around the world.

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

- EarthCube and its European equivalents - data and data delivery
- USArray and IRIS – Geophysics and earth observation
- International Ocean Discovery Program
- International Synchrotron facilities (USA, Japan, Europe)

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 Earth's crust provides many crucial services essential to the wealth and health of society. It provides the platform on which we live, the mineral, energy and groundwater resources on which we depend and increasingly serves as a repository for our hazardous wastes. Viewing the crust in terms of the services it provides, gives us a new narrative for the geosciences in the way that ecological services have for the environmental sciences. It focuses attention on the emerging need to define just how much our crust can provide and thereby informs future choices concerned, for example, with provisioning a secure and sustainable energy supply.

Consideration of the research infrastructure needs of the Natural Resource Management sector in terms of a crustal services approach may result in the development of a more thoroughly integrated program and infrastructure portfolio.

Advanced Physics, Chemistry, Mathematics and Materials

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

Alignment of research challenges that cross capability areas should be used to facilitate collaboration and the review should attempt to identify these areas and opportunities. For example many of the current research issues facing the earth and geospatial communities have very strong overlap with those proposed in the Advanced Physics, Chemistry, Mathematics and Materials sections.

These include but are not limited to:

(1) Mathematical modelling and simulation of earth processes including geochemical evolution of the planet and fluid dynamics of the mantle,
(2) New sensor and geophysical tool development and miniaturisation of sensors for deployment in UAV systems and the utilisation of drone swarms in sampling and earth observation in remote environments,
(3) Precision measurement at varied length scales related to geodetic earth measurement,
(4) High throughput geochemistry laboratory developments and resulting data handling workflows which are currently revolutionising geochronology science and mineral exploration processes in Australia,

National Security

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

In many parts of the world rapid growth of urban populations is exposing unprecedented numbers of people to the risk of devastating natural hazards such as destructive earthquakes, tsunamis, explosive volcanism and extreme weather events. Earthquakes in India and China, and tsunamis in the Indian and Pacific Oceans have taken a terrible toll on human life in the first decade of the 21st century. While such events remind Australians of our comparative fortune in living on an ancient and stable continent, they also warn us that we live in one of the Earth's most dynamic regions. We share our tectonic plate with India, and with our northern plate boundary extending through Indo-China, Indonesia, New Guinea, Polynesia and New Zealand we are rimmed by a zone at particular risk of catastrophic earthquakes and volcanic eruptions. Much of this region is characterized by poor building standards. It is likely that we will soon experience an earthquake that claims more than one million lives *(see The Next Catastrophe).* Any such disaster in our region will significantly impact Australian interests, from basic humanitarian considerations through to regional political stability.

Australia itself is not immune from earthquakes. The 1989 Newcastle magnitude 5.6 earthquake claimed 13 lives and resulted in about $4 billion in damage. Every 20 years or so Australia experiences an earthquake with at least 30 times more energy than the Newcastle quake. So far they have all occurred in remote regions, but we have little understanding of why they occur where they do. With our earthquakes typically inducing high ground accelerations, comparable to the 2011 Christchurch quake, such a quake within a few kilometres of one of our larger cities could result in profound damage and significant loss of life.

In this context there is no consideration given in the National Security capability section to either energy security or natural resource security. Australia is particularly vulnerable to threats to gas and electricity supply. Concentration of power generation infrastructure in regions of significant seismic hazard (such as the Gippsland Basin) put continuity of supply at significant risk in the event of a moderate to large earthquake.

Better understanding of crustal stability (and the related mantle state) as well as more research into nascent energy technologies is required to address these issues. Of particular importance is additional capability designed to understand the impact of human activity on the state of the Earths crust. The development of unconventional energy systems and the subsurface storage of waste materials have the potential to trigger significant earthquakes. Significant new deployments of earth monitoring systems across sedimentary basins will facilitate research into human impacts the state of the crust, the impacts on basin contained resource systems (including groundwater) as well as more fundamental research into the formation of the Australian Plate and its surrounding ocean basins.

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 emerging underpinning research infrastructure directions are generally good. Of particular relevance to the Geosciences are the requirements for, (1) high performance computing, high capacity networks and secure fast storage, (2) increased capacity and precision in the geospatial and earth monitoring space, and (3) digitisation of data to support national scale research programs that rely heavily on historical data, such as the Uncover initiative, will be critical.