2016 National Research Infrastructure Roadmap Capability Issues Paper

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Declaration of Interests

Professor Smith is Vice-Provost (Research & Research Infrastructure) at Monash University having responsibility for the oversight and management of the universities research alliances, tech transfer and research infrastructure as well as developing and implementing strategies to meet future university infrastructure needs.

Response Preparation

Contributions to the submission below were canvassed across the university with a focus on current NCRIS activities supported at Monash University as well as some new technologies we believe should be considered for the next NCRIS funding round.

INTRODUCTION

Monash University welcomes the opportunity to respond to the National Research Infrastructure Capability Issues Paper authored by the Expert Working Group as the first stage in developing a Roadmap to advise on Australian investments in research infrastructure for the next decade. Over the last ten years the Monash University research strategy has supported significant investments in both research infrastructure and appropriate cognate technical expertise. These capital and operational investments coming from a mix of government (State and Federal), philanthropy and a substantial university funding commitment. In the context of this document, there has been significant capital and operational investment though the NCRIS scheme. In regards to NCRIS, Monash is strongly involved in and committed to, the Australian National Nanofabrication Facility (ANFF) hosting the Melbourne Centre for Nanofabrication (MCN), hosting the EMBL Australia Secretariat, the National Imaging Facility (NIF), Auscope, Bioplatforms Australia (BPA) through the Monash Bioinformatics, Proteomics platforms and the Monash Antibody Technology Facility (MATF) and the Australian Phenomics Network (APN). In addition, Monash is the lead agency for the Australian National Data Service (ANDS), co-lead of the RDS VicNode and lead of the Nectar Characterisation Virtual Laboratory, and has a partner share in NCI. Together, these various investments into research infrastructure and engagement with NCRIS have allowed the establishment of an integrated network of world-class technology platforms that underpin the university's research excellence as well as the national research communities activities and respective research goals. Each platform has dedicated management, governance and oversight, meaning they are focussed on the delivery of high quality services, can make decisions quickly and can create solutions for academic and industry researchers. Certification to the International recognised Standard of Quality Management (ISO9001) also differentiates the university's research platforms. Operating a quality management system ensures the platforms. These core technology platforms are all readily available and easily accessible to any collaborating or other academic researchers as well as to industry partners. The goal here is to provide cutting-edge research infrastructure and supporting expertise to help remove barriers to excellence in research and to encourage collaboration. Research infrastructure is also intimately linked to our local and national ability to recruit and retain high quality scientists from overseas. Such individuals expect and require access to the best facilities to effectively address the most important scientific questions.

Monash hosted research infrastructure is also an important part of a vibrant environment of technology and research at Clayton in the South East of Melbourne. These includes CSIRO's Clayton site, the Australian Synchrotron (ANSTO), the Melbourne Centre for Nanofabrication (MCN), and one of Victoria's largest teaching hospitals, Monash Health and a soon to be built specialist heart hospital. Working closely with these partners has recently led to the establishment of a number of cross institutional capabilities (eg the SIEF funded Biomedical Materials Translation Facility (BMTF), a joint Monash, CSIRO, Hudson Institute initiative) and a large translational/clinical set of facilities at the new Translational Research Facility (shared funding model between Monash, Hudson Institute and Monash Health). Access to these partnered capabilities is shared across the precinct and beyond. In addition, many of our platforms form part of Victorian capability networks (eg Victorian Biomedical Imaging Capability (VBIC) and the Federated Association of Victorian e-Research (FAVeR)) as well as integrating into many national (NCRIS supported) and international networks (eg EMBL). As we move forward, the smart platforms of the future should we believe adopt a network-centric platform approach and also likely encompass complex arrays of computational (software and hardware) and physical components seamlessly integrated with the ability to synthesize the flow of information in real time.

We also support many of R&D focused large, medium and small companies, indeed, about 30% of available platform time is supporting industry users. Therefore, our research infrastructure is very well placed to not only support the vibrant research at Clayton but also that of our local and increasingly, national and international industry partners and academic collaborators. Platform ISO 9001:2008 certification (12 platforms are certified, a total of 24 certified by the end of 2016) gives our researchers, academic collaborators and industry great confidence in terms of supporting and enabling research and industry engagement. In this context, access to research infrastructure is proving to be a vital conduit to link university researchers and our research collaborators from both academia and industry. Leading researchers are attracted to the platforms because of their proven quality, expertise, networks and focus. Industry is attracted because it can access a quality assured, one-stop technology shop and a seamless, uniform research service across the university. Access to this high quality network of platforms has been a game-changer for how the university collaborates with industry. Commercial partners now have a central point to initiate collaboration in any particular area and the university has the capacity to deliver a high-quality, timely and responsive service.

National Research Infrastructure Policy Issues:

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

Since the original NCRIS investments a number of new capabilities have emerged and some of the identified and supported capabilities have evolved and as such we suggest the following new capability areas should be considered in the road mapping process:

1) Instrumentation Design and Fabrication Capability: Aim: To provide the infrastructure to design and build new instrumentation that will deliver fundamentally new capabilities for the characterisation of matter - from protein structures to minerals to advanced functional materials. The Instrumentation Design and Fabrication capability would provide the expertise and equipment that can develop, design and build instruments to enable the implementation of new characterisation methods, not commercially available.

Australia has exceptional expertise in the theoretical and conceptual development of new imaging and diffraction methods for the characterisation of matter using electron, light, x-ray and neutron radiations. However, the practical implementation of these new methods often requires instrumental developments that cannot be realised within Australia.

This capability would provide a hub of instrument design specialists equipped with the infrastructure to build, test and prototype new characterisation tools, as well as modify and extend the capabilities of existing instrumentation. This will deliver entirely new characterisation instruments to solve problems that are beyond the reach of current, commercially available instrumentation. Furthermore, it will enable the development of "linking" instrumentation, which enables the same specimen to be examined within multiple instruments with complementary capabilities, so the data can be correlated and impact maximised.

This capability will be a hub (possibly located at the Australian Synchrotron) that provides a nexus between Australia's

- diffraction and imaging physicists and characterisation specialists
- its characterisation instruments, from major national facilities (AS and Opal) to university-based instruments
- the instrumentation industry, which this will help to enable and stimulate
- the scientific community that is underpinned by characterisation capabilities.

The Instrumentation Design and Fabrication capability could provide capabilities in systems and software engineering, precision machining, 3D Printing, electronics design, robotics, component fabrication and assembly and computer control and automation.

2) Safe and Sustainable Mobility: Mobility and transportation play a fundamental role in Australian society, central to economic and social prosperity and individual health and quality of life. In this context, disruptive technologies pose both opportunity and challenge. The opportunity is significant improvements in energy use and environmental sustainability as well as economic and logistic efficiency. The challenge is to achieve these efficiencies with equivalent improvements in road/transport trauma and workplace injury. Without a coordinated research input, the value of new efficiencies may be compromised. For example, the integration phase of driverless vehicles integration into the existing transport network will demand significant research. The transition phase is likely to be measured in decades.

While there is considerable capacity across the nation, there is no national coordinating body to guide robust policy, legislation, regulation, facilities and operational processes. There is a serious risk that Australia will fall behind in the new mobility age. The US-based MCity project http://www.mtc.umich.edu/test-facility and its Australian equivalent (the Australian Driverless Vehicle Initiative http://advi.org.au/ and equivalent) are examples of cooperative activities that will be important for autonomous vehicles and road transport, but these will not go far enough to support the development of a safe sustainable system across all transport modes. There are also positive initiatives at state government levels towards all-of-transport strategic planning (e.g. the newly formed Transport for Victoria, bringing together private and public transport entities). However, investment in a research platform for evidence-based development for a new era in mobility, remains fragmented.

To address the challenge of disruptive technology, the existing diverse research capabilities in Australia require integration and management - a national coordinated research effort. Monash University has a breadth and depth of research capacity, proven record and international reputation for excellence in research leadership in Transport and Injury

Research through its Accident Research Centre (MUARC), Public Transport, Rail Institute, Mobility Design Laboratory, Institute of Transport Studies and the Monash Alfred Injury Network. There are existing key research platforms in simulation and human factors, human-machine design, engineering and intelligent transport systems, and driver and vehicle monitoring. Monash has solid partnerships with government and industry and with key transport and safety research hubs in Australia (Australian Road Research Board, UNSW TARS, QUT's CARRS-Q, University of Adelaide's CASR and Curtin's C-MARC) and internationally (e.g. University of Michigan's UMTRI and Virginia Tech's VTTI in the US and in the EU - the Netherland's SWOV and Sweden's VTI).

Australia could provide the physical and intellectual capacity to formulate and drive a coordinated response to disruptive technologies

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

We believe that an extra characteristic should be independence. We see this to be particularly important when looking at nationally networked capabilities where there could be potential real or perceived conflicts in resource allocations. In this context, national benefit should also be seen as a governance driver to help ensure local investments are made available nationally and out into industry.

Whilst the national research infrastructure is available to users across the country, in many cases the majority of users are drawn from the region surrounding the infrastructure. We would thus argue that for certain capabilities, greater emphasis should be placed on regional (potentially state based) networks of infrastructure capabilities that are coordinated nationally through a federated organisation. For example, in the case of molecular imaging (highlighted in the issues paper) the production and supply of short half-life radiotracers necessitates a maximum transport time of practically 1-2 hours from the production site. Furthermore, in the clinical/translation space, research is often conducted on defined patient cohorts where patient recruitment and sampling needs to be done locally.

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

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

Yes, access to unique international capabilities can provide Australian scientists with the opportunity to carry out research in facilities that are either unique and/or at a more sophisticated stage of development than those available in Australia. Some such facilities are unique, simply because of the level of investment, for example, the currently established multi-$billion high-energy X-ray free electron laser facility in Germany. In the longer term, some capabilities may well be developed or adopted in Australia, it may thus be desirable for Australian researchers to gain experience overseas so that they can accelerate their research once the equipment is available locally. There are clear examples that links to international facilities has led to significant development of core capability and expertise. For example, through the associate membership of EMBL Australian researchers have privileged access to EMBL capabilities These include access to the European Bioinformatics Institute (EBI) and establishment of local training programs that provide cutting edge skills development to Australian researchers. Through our associate membership of EMBL, we strongly believe that in the longer term the informatics coordination framework ELIXIR represents the direction that future life science data, capture, storage and delivery needs to go. It has become clear that bioinformatics has become the critical discipline in the life science area, providing answers to the challenges of managing the research data deluge. Indeed, ELIXIR has emerged as the only viable and thus far successful solution for the collective European management of data. Finally, there are many examples where negotiated access and participation in international initiatives has led to Australian involvement in a number of significant international collaborations that otherwise would not have occurred.

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

Yes. Research Infrastructure cannot be considered in isolation, the increasing sophistication of these technologies frequently requires high level dedicated expertise. We strongly believe that it is critical that strategic infrastructure is run by highly skilled and motivated people with the management and technical expertise to run sophisticated platforms. It is very hard to find funding support for these individuals and often it is difficult to recognise and reward performance through traditional University or Institute employment models (i.e. "teaching and research academics", "research fellows" or "professional staff"). In this context, it is critical that career development for these skilled individuals is part of the equation.

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

Many of the NCRIS funded capabilities run sophisticated training programs and provide access for research users (students and more senior researchers) to specialised expertise and advanced techniques to support optimal application of the infrastructure. In addition, there are focused initiatives such as the Australian Research Council Industrial Training Hubs which could provide an opportunity to assist in training and skills development.

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

We believe that, yes, there is a strong institutional responsibility to support the development of infrastructure ready researchers. Monash has shown successful examples of working with the local infrastructure companies to provide capacity and upskilling of the next generation of researchers (eg. HMSTrust partnership with Perkin Elmer). However, we also believe there could be great value in taking a more synergistic approach that involves research institutions, research infrastructure platforms/capabilities and the relevant national and international communities working together to develop and implement (nationally) these types of programs.

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

We believe that the guiding principles outlined in the issues paper are appropriate. The principle that all our technology research platforms operate under the guiding principle of open access that, gives equal access to internal users, external collaborators and industry users. We believe that this helps build a culture of open sharing and helps us realise the full value of our investment in the capability. Finally, and in this context, we believe meritorious access should be prioritised if capacity becomes limited.

We would suggest that a KPI should be the measurement of adherence to access principles to ensure hosts and operators are accountable for upholding the collaborative intent of the program.

Finally, we would argue that there should be the capacity to offer partially or fully subsidised access for early career researchers and industry users (start-ups/SME's) who may have insufficient funds to gain access through standard access fees.

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

The university recognises that "defunding and decommissioning" needs to be considered, both in light of a limited funding pot and also that priorities can change, the nature of infrastructures evolves and/or disruptive technologies may appear and finally, when performance is not as expected. All our platforms undergo a thorough five-year review which focusses on need (academic and industry), relevance and performance. The results of the review then guide the university as to whether to continue support, or wind down facilities in a rational manner.

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

We strongly believe that any investment in research infrastructure should be based on a sound business case that considers, local, national and industry demand, having the expertise to deliver the capability and alternative access to local or in some cases even national infrastructure. We also believe that any investment should be based on the principle of equitable access to users based at the host institution and from other institutions and sectors (eg. Industry). While financial commitments from a broad and highly engaged research community are essential to support these investments in national research infrastructure, the fundamental commitments to any new capabilities should, at least in part, come from Commonwealth and State government sources. Finally, any investments should be to enhance existing infrastructure capabilities at sites where there is a demonstrated track record in delivering timely, quality (certification or accreditation where possible) outputs to the broader academic and industry research communities.

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

<u>The University strongly believes that all our recognised technology platforms should be operating under at least ISO 9001 certification.</u> We currently have 12 platforms ISO9001 certified (including the NCRIS supported proteomics, antibody production, Centre for Nanofabrication), the remaining 12 will undergo certification before the end of the year, including the NCRIS supported Monash Biomedical Imaging (MBI) and Monash Bioinformatics Platform. In some cases, we require our platforms to meet more stringent regulatory standards such as ISO 13485 (medical devices) and ISO 15189 governed by NATA (eg the MHTP Medical Genomics facility). Accreditation/certification gives researchers, academic collaborators and industry great confidence in terms of supporting and enabling research and industry engagement. Operating a quality management system ensures the platforms processes are clear, infrastructure is performing optimally, accessibility is simple and they have the ability to ensure expectations are clearly set to to deliver high quality outcomes. In this context, access to research infrastructure is proving to be a vital conduit to link researchers with research collaborators from both academia and industry. Leading researchers are attracted to these platforms because of their proven quality, networks and focus. Industry is attracted because it can access a quality assured, seamless, uniform research service across the university.

The specific nature of standards and accreditations will need to be reviewed on a case by case basis, given the breadth of research capabilities, testing requirements and communities they engage with.

CAPABILITY FOCUS AREAS:

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

Interestingly, the NCRIS funding model has been studied extensively by a number of international organisations (ESFRI in Europe, NIH-US) and Australia, through NCRIS, is seen as a leader in setting priorities, developing national infrastructure strategies and implementing a culture of shared access and collaboration. However, where Europe in particular has perhaps moved ahead, has been the drawing together the different capabilities and is taking a more "systems based approach. For example CORBEL (COordinated Research infrastructures Building Enduring Life-science Services) was established to specifically bring together all the European capabilities that deliver to the life sciences. Data collection, processing distribution and analysis is considered paramount in Europe and in this context, CORBEL reports into ELIXIR which is the European research infrastructure for biological data. Models for implementation and operational best practice do need to be undertaken on a case by case basis, but we should not overlook the excellent infrastructure operations established in Australia, which are considered by many, to be more advanced than many of our international peers.

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

No response.

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

A major factor influencing the sustainability and value of research infrastructure has to be the level of uptake (by both industry and academic researchers) along with the value of the outputs. One mechanism for at least prioritising financial investment, perhaps from the State as well as Federal governments, might be around levels and breadth of uptake and the proportion of the operational costs generated by the national infrastructure network. Other potential areas for financing that could be explored could include; Institutional co-investment aligned with local academic and industry research needs and expertise, State government co-investment aligned with local research priorities and industry needs, industry co-investment aligned with strategic needs, philanthropic investment in defined research areas and finally, there are (as we have found) significant opportunities for co-investment / partnerships with instrument / technology vendors for instrument / workflow etc., development

HEALTH AND MEDICAL SCIENCES

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

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

Phenomics/APN: The molecular revolution has brought unprecedented capacity to understand variation at the level of the genome, proteome, and metabolome. Such variation is now better understood and more easily and cheaply characterised than the physical traits that organisms exhibit. This disconnect inhibits true vertical integration of the life sciences, and prevents the translation of omics research to higher levels of biological organisation. At present, therefore, the promise of the molecular revolution to improve our understanding higher-order phenomena, such as ecosystem processes and climate change adaptation, remains unrealised. Linking phenotypic variation to genomic, proteomic, and metabolomic variation therefore represents the major challenge in harnessing the power of the biomolecular age.

Monash University is ideally positioned to play a significant role in the improving the integration of genomic, phenomic, metabolomic and proteomic facilities to capture new scientific advances at the intersection of these areas. Monash hosts genomic and proteomics platforms (platforms.monash.edu), has considerable expertise in metabolomics, and already hosts Australia's first high-throughput animal phenotyping facility, but is presently focussed on a small range of species (mainly marine and terrestrial invertebrates) and a limited range of phenotypes. Leveraging Monash's existing capability and expanding the scale of the animal phenotyping facility will dramatically increase Australia's capacity to link the genome, proteome, metabolome, and phenome, and will thereby overcome a major bottleneck in biology. This will position Australian researchers to address multifaceted societal problems, such as adaptation and mitigation of climate change, in an integrated manner at multiple levels of biological organisation from genes to ecosystems.

The advent of high throughput, low cost genome sequencing has revolutionized our capacity to identify the genes which cause or influence disease. The subsequent analysis of these genes is therefore critical for providing functional insights into how disease develops and for developing novel therapies to treat it. Cells and animal models are central to these efforts and mice, in particular, represent the gold standard for studying the impacts of altered gene function and for the development of pre-clinical platforms for testing novel therapies. To date the Monash University node of the Australian Phenomics Network (APN) has serviced the needs of the Australian biomedical research community by facilitating the importation and generation of mice using the resources of the European and North American EUCOMM and KOMP ES cell programs. By leveraging against this >$100 million international investment we have generated > 120 different mouse strains for the research community, underpinning >$30 million in funded research projects and supporting researchers in >30 Universities and Institutes Australia-wide. In addition, we have archived many thousands of sperm samples from these valuable mouse strains, safeguarding Australian researchers and facilitating the exchange of these strains amongst the research community. The APN experience has been that facilitating National and commercial access to resources and expertise of this nature has helped considerably in streamlining Australia's research effort. In addition to "machines in labs", we trade on our expertise and experience in facilitating biomedical research. We have removed duplicated technologies, provided considerable economies of scale for mouse production and we have facilitated the involvement of smaller Universities, Institutes and SME's for whom access would have previously been challenging.

The next phase of NCRIS funding comes at a transformative and exciting time for our understanding of genetic disease. The development of "CRISPR technology" has been rightly hailed as a scientific revolution. It allows scientists to "engineer" the genome of cells and organisms and it holds almost limitless promise for transforming the manner in which we study gene function. A major aspect of this advance lies in enabling the precise, efficient and rapid generation of laboratory organisms which carry the exact mutations identified in diseased human populations. The availability of these disease models will be critical in developing the next generation of therapies. The APN has been a National leader in the implementation of this technology, generating >200 CRISPR'ed mouse models for in <18 months. In the future we see the APN playing a central role in the generation of CRISPR modified cells and organisms, feeding a pipeline for novel therapeutic discovery. These resources will also be critical for more basic biomedical studies aimed at elucidating the molecular basis for the development of disease. The Monash APN node will further develop our expertise in CRISPR genome modification to include the development of rat, rabbit and embryonic stem cell disease models. The vision for the APN is to oversee an accessible pipeline for biomedical discovery which starts with a sequenced human genome, is facilitated by the ready availability of organisms and cells precisely engineered to carrying disease genes and which ends with a deeper understanding of disease etiology and the development of novel therapies.

Bioplatforms Australia BPA/Omics: It is clear that over the next decade we will see "omics" sciences technology advancement and associated big data explosion realise the research, social and economic benefit across almost all sectors of the Australian research and innovation system. Understanding of health and wellbeing will be matched with new healthcare regimes for those that suffer disease based upon the 'omics. Precision medicine will see new treatments, provided more cheaply and effectively to the population. Agricultural developments will deliver crops protected from disease, productivity optimised and food qualities maximised to ensure value added industries prosper. Environmental surveying, land management and rehabilitation will all be informed by new decision making tools based upon 'omics data, supporting both government policy and industrial activity. Bioplatforms Australia (BPA) provides access to cutting edge bioinformatics capabilities, proteomics (including monoclonal antibody production,) metabolomics and advanced genomics.

The application of "omics technologies" has moved far beyond being discovery tools and are now used for example for the ongoing monitoring of biological systems – manufacturing of biologicals, clinical trials, food quality and environmental health and rehabilitation. Biomolecular enablers such as the "omics" is having true and measurable impact on the Australian research and innovation system.

Monash has a very close involvement with and strongly supports BPA, through its investments into bioinformatics and bioinformatics training, supporting the Biomedical Proteomics Platform and finally through Australia's only dedicated, fully automated Monoclonal Antibody Technology Facility (MATF). These capabilities have been crucial, supporting both Monash and the broader academic research community as well as providing a very valuable tool for industry engagement. A great example would be the recently established Pfizer Centre for Translational Innovation (CTI), the first such centre outside the US. Having MATF located at Monash persuaded Pfizer to establish the centre. Continued investment in BPA is critical for both future leading edge research as well as supporting local, national and international industry.

EMBL Membership: Monash very strongly supports continued associate membership of EMBL. Through its associate membership of EMBL, Australian researchers not only have access to the many (worlds best) platform technologies, they will also have access to many other unique tools and resources. For example, EMBL-EBI are developing some significant resources such as the ChEMBL chemical compounds database, the Gene Ontology and the Variant Effect Predictor Tool. These specialist capabilities are available to academic researchers, industry and the clinical community. These tools can be applied to analyse the effects of genomic variation on human, animal and plant health, on the progression of diseases such as cancer and on the evolution of pathogens. It's the application of these kind of capabilities that will open the door to the development of true personalised medicine strategies, drug discovery, solutions to pest control and will impact on the agricultural and food industries. Finally, through these international relationships Australian scientists will have access to unique clinical and other data bases. Finally, we argue that the support and expertise within EBI will greatly facilitate Australia to build the appropriate organisational structures and networks required as a prelude to join ELIXIR.

Imaging AMMRF/NIF: Optical Microscopy has experienced a resurgence in the past decade, and areas such as correlative, lightsheet and super-resolution microscopy are becoming established mainstream technologies. Both nationally and internationally, however, these areas suffer the lack of well-developed non-proprietary software tools and/or toolkits that would enable wider deployment of advanced analytical instruments. Continued development of these and similar instruments is driving improved resolution, speed and sensitivity and all such activities result in increased size and complexity of datasets.

Skills and training remain a key element underpinning microscopy infrastructure, crucial for ensuring that Australia remains at the forefront of scientific discovery. The field of bioimage analysis and informatics is rapidly expanding, and unless there is support for skills and training in this area, demand will outstrip supply and become a significant bottleneck for the research community in the near future. We therefore emphasize the following key issues:

1. Further support is required to accelerate the development and integration of open source (non-proprietary) software tools in order to create seamless workflows from microscopy imaging to data analysis and then to data storage/archival/publication.
2. Computational support for developing required software tools and services, and for training the next generation of researchers, should be integrated and preferably embedded into imaging teams and core facilities.
3. Operational support be made available for instrument maintenance and upgrades to enhance the longevity of research instrumentation.

Monash has made a significant investment into advanced Biomedical imaging. With both state government and university support, we have established Monash Biomedical Imaging (MBI) which is now seen as a major player in both the national as well as international biomedical imaging arenas. MBI which has state of the art imaging capabilities (MRI, PET, SPECT, CT and hybrid MR/PET technologies) for both clinical and preclinical research. Furthermore, MBI is uniquely positioned next to the Australian synchrotron with the imaging and medical Beamline (IMBL) terminating immediately adjacent to the MBI building, providing users access to a world unique “one stop, biomedical imaging shop”. Furthermore, recent SIEF funding ($10million) has supported a partnership between MBI and CSIRO to develop the Biomedical Materials Translation Facility (BMTF). This capability which comprises dual modality non-invasive (PET/MR) clinical imaging, 3D tissue printing and clean rooms to produce next generation biocompatible materials address a local and national industry unmet need.

Access fees for discovery research capabilities can to a degree support operations, they do not however support upgrades and renewal of technology, thus continuing investment into the National Imaging Facility (NIF) is critical. Access to these capabilities will help build the industries of the future through the translation of imaging research discoveries and technologies through startups; partnered innovation with small to medium Australian enterprises (eg. Cyclotek); and commercialisation with established large industry partners (eg. Siemens).

It is clear that advanced imaging technologies are having a major impact in most areas of Biomedical research and clinical translation – metabolic imaging is critical and must be integrated, but the rate of MRI and other imaging developments is accelerating, and we believe that the impact of the rapidly developing MRI technologies was perhaps underplayed in the Issues Paper, and for Australia to remain a leader in this field substantial future investment is essential.

Over the past decade research investment has focused on Buildings and instrumentation. As NIF evolves, more emphasis should be around specialization and expertise and to promote greater integration across these specialised sites, recognizing that all sites will require “entry level” equipment and expertise. While some technologies have become ‘commodity’ in some applications, we recognize there is an increasing distinction between turn key clinical systems that support basic imaging requirements and research based systems that often feature new workflows, modified instrumentation and new software systems for control and data analysis. These are essential for clinical translation and commercialisation. In this context, we also believe support is needed to help in the modification of existing and the development of next generation technologies and instrumentation. For example, Monash through has partnered through joint appointment,)with Helmholtz in Julisch Germany to work on the development of novel biomedical imaging detector systems

The Australian research advantage is not through working in isolation with all expertise in one location but integration and linkage of distributed expertise including multimodal imaging capabilities (eg advanced research in magnetic resonance, neurophysiological and molecular imaging). Whilst the national research infrastructure is available to users across the country, the majority of users are drawn from the region surrounding the infrastructure. Therefore, greater emphasis should be placed on regional (potentially state based) networks of infrastructure capabilities that are coordinated nationally through a federated organisation. For example, the production and supply of short half life radiotracers necessitates a maximum transport time of practically 1-2 hours from the production site. Thus the geographical needs for key infrastructure such as cyclotrons needs to be examined.

The emphasis in the Issues Paper placed on PET, radiotracers, and cyclotrons is highly appropriate and strongly supported by the imaging research community. Supporting the existing infrastructure, in particular with operational support, will ensure affordable and sustainable research and innovation capacity into the future. Other emerging trends include: emerging machine learning technologies and artificial intelligence for interrogation of massively large imaging datasets (an area of strength at Monash), cloud based access to dedicated high performance computing for real time image analysis (eg MASSIVE). The development and application of these technologies will lead to increased innovation with industrial partners, accelerated transformation of new technologies for industry growth, and improved effectiveness of the translation of discoveries for improved healthcare outcomes.

TIA/ Novel small molecule therapeutics: Whilst the current National Research Infrastructure Capability Issues Paper is right to point out recent growth in biologics discovery, translation of medical discoveries into small molecule therapeutics and improved understanding of receptor function remains the mainstay of international Pharma (and is especially critical in medicines for the developing world where most biologics are impractical) and is a critical requirement for the nascent Australian drug discovery landscape. Infrastructure to support these activities is therefore similarly critical. Indeed, recent advances (and indeed anticipated continued advances) in structural biology, made possible by national investment in eg the Synchrotron and Electron Microscopy, dictate that the roadblock to effective structure-based drug design is shifting from structure determination to mechanisms to identify ligands to interact with those targets. In this regard we suggest the need for continued national investment in the following area.

High throughput screening (HTS) – infrastructure to allow identified and validated targets to be screened against appropriately curated libraries of drugs and drug like molecules to isolate lead-like molecules for progression into drug discovery and chemical biology programs. Screening capabilities exist nationally notably at WEHI and Griffith, but there is not a concerted national program of support or access

Fragment based screening (FBS) - infrastructure to allow screening of smaller molecular fragments against a known target. The advantage of fragment based screening is the ability to sample a larger diversity of 'chemical space' since the fragments are smaller than the drug-like molecules used in HTS. This in turn allows much smaller libraries to be used. FBS requires investment in Nuclear Magnetic Resonance (NMR) spectroscopy to identify initial fragment hits and investments in Surface Plasmon Resonance (SPR) and crystallography to refine those hits. Recent advances in microscale thermophoresis provide additional powerful means of assessing ligand interactions with small quantities of material and investments in these areas should also be considered. Notably investments in these areas will support national interests in structural biology – another key focus area. In general NMR has been much less well supported by national infrastructure schemes when compared to crystallography - but both are critical and complementary

Screening library curation, storage and distribution – screening capabilities are critically dependent on the libraries that are used to screen, the quality of these libraries and means of storage and distribution of these compounds to screening facilities. Compounds Australia fulfils some of this need with respect to distribution, but does not have the capability to store off site (in case of eg loss by fire), or to provide cold storage and does not curate libraries.

One current capability that was previously funded through NCRIS and supports some of the activities in these areas is Therapeutic Innovation Australia (TIA). We fully support their activities and would support ongoing funding for this initiative through the National Research Infrastructure Capability Roadmap. Key areas under the TIA remit that must be maintained include access to infrastructure in bioanalysis, integrated pre-clinical testing, pharmacometrics and translational medicinal chemistry - the latter providing the link between screening capabilities and expansion of hits from the screens into nascent drugs. This is equally applicable to biologics and small molecules. One area that is currently not well served in the Australian landscape is access to larger preclinical testing facilities, especially dogs. Australia has good facilities for small animals (rats, mice) and access to non-human primates, but typical pre-clinical progression series would include assessment in dogs and this is an area that is not well served nationally.

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

Regenerative Medicine: We contend that infrastructure to support the emerging landscape of regenerative medicine based therapies is an urgent addition to the national research infrastructure landscape. We are in full agreement with the statement within the NCRIS capability document surrounding regenerative medicine that suggest that " a national capability providing researchers with advice and access to cell lines, protocols and training should be considered. This would assist Australia to develop regenerative medicine capability to significantly improve health outcomes."

There is a requirement to develop a mechanism for ensuring Australia's strong leadership in the Regenerative Medicine sector translates into a practical benefit for as many Australians as possible. The tantalising promise of this field of medical research is that it has the potential to impact on a nearly limitless range of diseases that afflict the human condition. In our opinion, no other area of medical science is poised to make such a broad clinical impact in the next decade. We wish to design and implement infrastructure that ensures we harness the potential of this sector to benefit the health of the Australian population and kick start innovation. We urgently need to capitalise on the very strong basic science base in this discipline so as Australia can position itself to become a major international supplier of regenerative medicine technologies and therapeutics in a market that is expected to grow to $50 billion by 2019.

The impediments to this occurring are twofold. A lack of an integrated pipeline of infrastructure and skill sets to facilitate movement of promising regenerative medicine based therapies into clinical trials and the paucity of local engaged commercial entities to promote their development. In attempting to develop a model of how these issues could be best resolved we looked for examples of best practice internationally. A number of significant North America and European initiatives have been implemented in the last decade backed by dedicated government funding, that target diseases of considerable burden with well integrated pipelines of regenerative medicine based therapies. As a result, many sponsored clinical trials of cell and regenerative therapies are underway in these locations. They serve as different templates on how centralised government funding can unlock the therapeutic potential of a strong basic research pipeline, and bridge the gap between basic discovery science and clinical impact.

From an infrastructure capacity building one of the most developed of these frame works is UK Regenerative Medicine Platform. The UKRMP addresses the technical and scientific challenges associated with translating promising scientific discoveries in this area towards clinical impact. Specific decentralized hubs have been funded to tackle specific issues that the sector has identified that impact on clinical delivery in the Regen Med sector. Collectively, the Hubs provide a world-leading program to promote the development of regenerative therapies. Each of the Hubs provides a UK centre of expertise/knowledge with the necessary critical mass to address key translational challenges and provide new tools, protocols and resources with broad applicability that can be utilised by other UK research groups in academia and industry. This is a different more focused approach than funding a competitive grant scheme and it tackles head on the infrastructure bottlenecks in translating particular technologies. It is a diversified model at different sites that draws on the UKs strengths at distinct research environments. In many ways it fits well with the dispersed nature of Regenerative Medicine Research in this country and such a model has been endorsed by the leadership of Stem Cells Australia. We call for the setting up of a network of reference laboratories for in stem cell and regenerative medicine to aid in translation of promising therapeutic approaches into the clinic.

Structural Biology: Monash University very strongly supports the "Issues Paper" recommendation that we should provide stronger support for structural biology infrastructure and capability across the country. To be competitive on the international stage, our structural biology community need access and time to carry out experiments at national and international synchrotron beamlines. Furthermore there is a need to support complementary technologies such as NMR, which is for example critical for fragment based drug development. Finally, we need to invest in disruptive technologies such as single particle Cryo-EM Electron Microscopy and ensure access to specialized supercomputing capabilities (such as MASSIVE) designed to rapidly (as close to real time as possible) process increasingly complex imaging data. As these new resources come on line, it is important that these instruments be properly linked and networked, for example to permit sample queues to be balanced across the nation and such that periods of downtime and maintenance can be coordinated. Further, given the large amounts of data output by such instruments (terabytes / day), access to extensive imaging related bioinformatics and supercomputing is critical. Such networked infrastructure has already been built and coordinated at Monash.

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?

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

Mathematics: Research in the mathematical sciences is of intrinsic importance as well as underpinning all technological innovations. Transformative discoveries often depend upon prior developments in mathematics. For example, understanding of prime numbers underpins secure online banking and communications. Modern mathematical research is a creative and social activity. It is widely recognised that intensive research programs at residential research institutes are one of the most successful methods for fostering mathematical research. Examples include the Newton Institute in Cambridge, Oberwohlfach in Germany, the Mathematical Sciences Research Institute in Berkeley, and the Banff International Research Station in Canada. Such institutes provide vital infrastructure for research in the mathematical sciences. They facilitate collaborations, and increase the international impact of research.

The need for the establishment of a national research institute for the mathematical sciences in Australia has been recognised for many years, and is a key recommendation of the Decadal Plan in the mathematical sciences. In 2016, Monash University and The University of Melbourne established the Mathematical Research Institute MATRIX (matrix-inst.org.au). Currently located in Creswick in regional Victoria, MATRIX enables mathematicians from all over Australia to collaborate with elite international researchers and with industry partners. Five research programs, each 1-4 weeks in duration, have or will be held in 2016, with many programs confirmed for 2017 and 2018. For MATRIX to be internationally competitive, funding needs to be increased and guaranteed over a longer term. A purpose-built venue with seminar rooms, collaboration spaces and accommodation capable of hosting up to 40 researchers is required.

Nanofabrication/ANFF/MCN: The Victorian node of the Australian National Nanofabrication Facility (ANFF Vic) node is a cooperative activity which brings together six Victorian universities (Monash, Melbourne, Deakin, Swinburne, La Trobe and RMIT) and CSIRO. The activity is headquartered at the Melbourne Centre for Nanofabrication (MCN) which is hosted and operated by Monash University. Although some of the node members have their own clean rooms and equipment, the majority of the Victorian capability resides at the MCN. This purpose built state of the art facility, built through funding provided by NCRIS, the Victorian State government and the participating members, houses clean rooms, biology (PC2) labs, office space and provides both sophisticated instrumentation and expertise to the Victorian academic community, industry as well as providing specialist capabilities nationally. Given Australia's success in the medical technology/device industry (eg ResMed and Cochlear), taken together both with this being a research priority of the Victorian government reflecting a strong interest in medical engineering amongst many of the participating organisations, medical technology has become a focus (albeit not exclusive) of MCN and its Victorian partners.

Monash university strongly supports continued investment into this first class capability. We were a little disappointed that the issues paper did not give much attention to biomedical engineering, which is a major Monash research priority. Indeed, the university has recently established the Monash Institute for Medical Engineering (MIME) which is a heavy user of the facilities at MCN.

We would see future infrastructure investments supporting the area of medical engineering including:

- Development of diagnostic and monitoring sensors suitable for in vivo use and remote interrogation
- Medical processes supported by microfluidics and lab-on-a-chip
- Extra-corporeal processes for tumour sorting and removal
- Nanomedicine
- Prothesis manufacture by 3D printing
- Nano-scaffolds for surgical procedures

- In vitro alternatives to animal testing and clinical studies
- Printed organs
- Biocompatible materials
- Bionic vision

Complementary research activities at Monash and collaborating partners will include studies on the development and interactions between next generation biocompatible materials and biological system, the development and application of implantable electrodes. Some of these research challenges are already supported by ANFF and have led to commercial products (e.g. the Vaxxas nanopatch). The focus now needs to be on integration and pre-commercial production and testing. The goal being to take a prototype manufactured under laboratory conditions through to a test product suitable for clinical trials. MIME which brings together clinical and engineering researchers would thus work closely with MCN to accelerate the discovery to market process.

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?

Additive Manufacturing: Additive manufacturing, encompassing activities more broadly in '3D printing', is a major area of research strength and focus at Monash University. The activities at Monash are comprehensive and world leading. The comprehensive nature is best summarised by the fact that 3D printing is a key activity in many departments, and faculties (including Engineering, Medicine, Science, IT, Art & Design) with core research nodes in Materials Science & Engineering, Mechanical & Aerospace Engineering, Chemical Engineering, Chemistry, Biology, Anatomy and Medicine. The 3D printing activity presently covers every category of printing available, and dissemination of activities from 1st year undergraduate teaching, to senior student design activities, to a new Masters degree in additive manufacturing (to commence in 2017), to world changing research.

In terms of world leading, Monash has well over 100 printers working around the clock, from small scale FDM (fused deposition modelling) printers, to large scale FDM, 2 x state of the art multicolour multimaterial polyjet printers, smart fibre printing (carbon fibre, Kevlar, reinforced composites), to the largest collection of metal printers in a single university in the world. In regards to metal printing, the Monash Centre for Additive Manufacturing (MCAM) platform culminates the worlds largest SLM (selective laser melting) and the large DLD (direct laser deposition) instruments routinely used in translating to industrial impact, to a 4 more metal printers covering the length scale and used for teaching and rapid prototyping.

To date, two of the faculties largest ever industry engagements have been in the area of metal printing, namely the engagement with Safran and Woodside (each being multimillion per year). To this end, we believe it is just the beginning, and the capability in additive manufacturing is not just a research interest, but the vessel that will allow transformation of the manufacturing industry across several fields, be it biomedical, aerospace, personalised products, or education. To realise the impact, the activities must be university wide, multidisciplinary, and at scale. The attainment of scale requires ongoing investment.

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?

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

In the section on Environment and Natural Resource Management, the mineral resources and solid earth aspect of Earth Sciences appear almost entirely left by the way side. This is particularly concerning given that the minerals industry continues to underpin Australia's economy (export earnings are ~ $140 billion per year). Solid earth geoscience research in Australia has historically outperformed all other fields of science at the global level. This competitive edge needs to be maintained and boosted as mineral resources become progressively harder to find, especially when the world needs to be moving to renewable energy technologies, with an increasing need of resources such as lithium and rare earth elements.

Monash University has a strong focus on the entirety of Earth Sciences, from atmospheric and environmental science to solid earth geoscience. It plays a major role in the national research community in this field through a strong research focus on techniques employed at the Australian Synchrotron, linked with analytical capabilities on the Monash Clayton campus, and the adjacent CSIRO facility, to form a world-class research centre. We echo the need for improvements in funding for technical support staff, large data sharing capabilities, and improved linkages in existing infrastructure. But we emphasise that solid earth geoscience needs to be an important part of the picture. In the future, there will need to be a more coherent focus on the geoscience research underpinning mineral exploration because current mineral resources are dwindling and there have been few major new discoveries for many years. The still embryonic UNCOVER initiative aims to generate stronger links between the minerals industry, government science bodies and university research to improve mineral exploration success. UNCOVER is thus heading in the right direction and we suggest that this should be encouraged, and perhaps broadened to include a greater breadth of Earth Science research; related infrastructure includes the facilities needed to complete national geochemical (isotopic and trace element) and geophysical surveys, and underpinning solid earth geoscience research.

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?

Drones, Sensors and Smart Analytics for Earth, Geospatial, Environmental Sciences and Natural Resources. Drone technology has exploded into many scientific disciplines and Australian industry with the advent of cheap, consumer grade platforms. Drones, or unmanned aerial vehicles (UAVs) are truly interoperable and align with multiple capability areas (e.g. solid earth geoscience, soils, hydrology, biology, ecology, environmental science, rural and urban geography, climatology, meteorology, civil engineering etc). The great challenges that face us now are not in the development of new platforms (although the technology will be and should be continually improving) but in the smart application of this technology, in the development of sensors, in the real-time/accelerated analysis of the big data it can collect and in the visualisation and storage of the data post-processing.

Australia has a unique landscape relative to many other nations, with its vast distances, climate extremes and large primary industries (mining, agriculture, forestry). We advocate that Australia needs *applied* UAV and associated analytics infrastructure, to feed the research community and natural resources, environmental and geospatial industries. Existing and successful NCRIS initiatives such as AuScope are entities that would benefit from accessing such infrastructure. Access to existing AuScope data infrastructure will provide a mature eResearch environment on which to build analytics platforms specific to the requirements of this program.

Emerging trends: There are four key trends that national UAV infrastructure and associated analytics will be able to address. These are:

1. *A need for multiscale data*. Satellite data is ubiquitous to multiple scientific disciplines, enabling us to sample vast swathes of landscape remotely. We require high resolution data within the scale gap between ground samples and satellite sensing, enabling us to calibrate and upscale/downscale satellite data (e.g. infrared spectral datasets used by the earth, environmental and biosciences).

2. *Cost-effective, rapid deployment often in unsafe and remote locations*. Examples would include time-series surveys, critical for tracking seasonal events or the evolution of long duration events (e.g. coastal erosion, creeping landslides, open pit mine subsidence etc). Data is also required in a timely manner in order to capture information of national and international importance, particularly after major catastrophic events (e.g. seismic episodes, floods, bushfires etc).

3. *Multi-sensing*. In order to solve many issues of scientific importance we sense the Australian landscape and subsurface using an array of geophysical techniques, cameras, and environmental sensors.

4. *A need for coherence*. The 'ecosystem' of scientific equipment data collection and data analysis requires increasing coherence.

Emerging capability: A national UAV and analytics infrastructure will provide facilities that are highly effective for strategic and cross-disciplinary research, if it brings together *capability users (earth and environmental scientists, biologists etc)* and *capability developers (analytics, visualisation etc)*. UAVs are relatively cheap, rapidly deployable, ideally suited for high-resolution surveys and deliver significant gains in terms of safety and low impact on the environment during deployment. The miniaturisation of sensors will enable UAVs to collect multiple data types in a single deployment (e.g. photogrammetry at the same time as temperature, humidity and CO2 sampling). In addition, multi-sensing over large areas of ground will be achieved with the deployment of multiple platforms as swarms. The technical challenges in achieving swarm deployments have been largely overcome, even in GPS denied environments. The regulatory framework is the remaining hurdle to this exciting capability. A third emerging capability is the smart use of UAVs to achieve surveys never previously achievable by aerial or satellite techniques. Examples of this include developing magnetometers for multi-rotor UAVs flying in formation and combining the approach with real-time identification of anomalies, in order to change formation and collect high resolution information over the anomalies. Similarly, the hopping of gravity meters through the landscape by UAVs enables us to massively reduce the time required for gravity surveys and opens up the possibility of high resolution gravity, which were not practical previously. Finally, there are emerging capabilities from IT and computer vision in the use of artificial intelligence (AI) to aid with the accelerated interpretation of visual and remote sensing 'big data' and to visualise such data in new and exciting ways (e.g. immersive visualisation for collaborative interpretation).

Monash is invested in applied UAV and analytics infrastructure. We have brought together a team of UAV pilot-trained earth and environmental scientists, archaeologists, biologists and civil engineers, alongside expertise in environmental sensor development, the use of artificial intelligence (AI) to aid with the accelerated interpretation of visual and remote sensing 'big data', swarm robotics and object avoidance engineering, immersive visualisation and IT specialists in data archiving and security.

UAV-related Infrastructure - A vision for the future:

1. A fleet of UAVs with a range of capabilities in manoeuvrability, flight duration, and lift with technical and maintenance support staff. This would include platforms for hire as well as platforms for deployment accompanied by appropriate pilots.

2. Dedicated training and a national institute with appropriate operators certification – UAV deployment is regulated by the aviation authority CASA. National infrastructure providing

platforms for research needs can provide piloting certification involving training in associated safety, meteorology and regulatory considerations. Further training to be provided in the analysis and visualisation of the data.

3. Development in sensors, analytics, visualisation and archiving to support the capabilities of the infrastructure. The infrastructure needs to be supported in a coherent way with highly skilled research staff developing the analytics and visualisation of the data in close collaboration with the user communities.

4. Accessible to publicly and privately funded users across the country, and internationally, with consideration given to merit-based public-sector Australian research; merit-based or partial cost recovery based public-sector international research; and the private sector at partial or full cost recovery.

5. An ambition to deploy long-duration UAVs (e.g. solar powered fixed wing models) to collect data automatically from the remotest regions of Australia, making us the first UAV-sensed nation in the world. All data to meet pre-competitive science and industry needs and made publically available.

UNDERPINNING RESEARCH INFRASTRUCTURE / DATA FOR RESEARCH AND DISCOVERABILITY

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

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

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

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

Monash's eResearch infrastructure and capability, which has been developing for nearly fifteen years, and which is mission critical to our research strategy and research impact globally, is internationally recognised by technology companies and some of the world's top universities for excellence. It is built around the key principle that direct engagement with the research communities is critical to ensuring that the infrastructure is developed to accelerate and support the research in the most optimal manner. The infrastructure is built and operated by the staff who engage directly with the research communities. Our experience and the success of our engagement model uniquely positions us to extract value from and critique federally funded research infrastructure initiatives, including the Underpinning Research Infrastructure and Data for Research and Discoverability Capabilities.

Data for Research and Discoverability

Monash very much supports the overarching Data for Research and Discoverability approach outlined in the Issues Paper, and strongly supports a full integration of ANDS, RDS and Nectar to establish a coherent entity. This would address the current arrangements that require us to reconcile the sometimes conflicting requirements of three separate entities. Governance of a new entity should be based on an independent board and chair. We affirm the lead agency model for such an entity, provided the lead agency facilitates the independence of the entity.

Among the most valuable eResearch infrastructure activities Monash has led, are those where we have combined the funding, resources and technical goals of the three separate programmes to deliver to a single vision and community – for example, the informatics (cloud, data and HPC) support for the National Characterisation community. Ground breaking initiatives such as the instrument integration work across Australia on the MyTARDIS platform has been supported using funding from all three programmes: ANDS, RDS and Nectar. Coordinating the three programmes into one entity will greatly streamline and accelerate the eResearch infrastructure programme, and will make the research infrastructure environment more effective for all concerned. A single entity will strengthen the direct engagement opportunities with the research communities (i.e. the single shop front). This will enable the research sector to drive its needs, and the single entity can respond to those needs while recognising the Government's desire to achieve greater integration and coherence.

Underpinning Research Infrastructure

The MASSIVE (Multi-modal Australian ScienceS Imaging and Visualisation Environment) facility is a critical part of the national HPC environment that currently lacks connection into the national infrastructure, even though it has received funding from the NCRIS underpinning research infrastructure programmes, including NCI. By the definition provided in National Research Infrastructure Capability Issues Paper, MASSIVE is a Tier-1 facility. It provides computing and data processing services to over 1,000 researchers across over 100 Australian organisations.

There needs to be a more coherent approach to the national HPC landscape, and Monash supports greater integration of HPC capabilities at all levels, including MASSIVE. It is also important if Australia adopts a tiered model of HPC facilities, as done in Europe. In this case, the merit allocation scheme will become a primary method of directing projects to the most appropriate tier. Where funded by national funding, allocation of computing time on computing facilities must be through a national merit allocation scheme that is fully independent of the organisation(s) providing the computing platform.

Industry engagement

Industry engagement is critical to the future. eResearch infrastructure needs to support partnerships between research and industry to continue to drive innovation in research infrastructure. Currently there are no schemes that seed fund and enable partnerships of this nature in Australia (compared with Singapore and the UK, for example). A programme along these lines would accelerate research collaboration between the research sector and industry. It is important to ensure that any such funding does not end up subsidising industry supply into the research infrastructure landscape, but enables new innovation.

International collaboration

We believe international collaboration is vitally important. The informatics support for the National Characterisation community (including, MASSIVE and the Characterisation Virtual Laboratory) has international recognition, and projects such as the €1B Human Brain Project wish to collaborate on the infrastructure and technology, which would bring significant value back to Australia. This informatics work does not have a natural home in one of the existing research infrastructure projects, and therefore the opportunity to leverage funding to promote closer international collaboration is lost. A more integrated approach to both data and HPC infrastructure would create better opportunities to capture all of the informatics work being done for a given community (for example, Characterisation) to establish international connection opportunities.

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

We believe that Australian membership (if possible) of ELIXIR would offer researchers enormous opportunities and advantage. ELIXIR is a cross Europe e-infrastructure, with a Hub located at the EMBL-EBI site in Hinxton, Cambridge and with Nodes in recognised centres of expertise in bioinformatics across Europe. Taken together, such a collective could provide computing capabilities and data storage on a previously unprecedented scale. Such a consortium would allow the integration and analysis of life science/medical data which can be made available on an open access platform with tools and standards developed to the benefit of users across the globe.

We strongly believe that ELIXIR represents the direction that future life science data, capture, storage and delivery needs to go. It has become clear that bioinformatics has become the critical discipline in the life science area, providing answers to the challenges of managing the research data deluge. ELIXIR has emerged as the only viable and thus far successful solution for the collective European management of data.

Countries that are or will become ELIXIR Member States benefit in the following ways from their participation in this infrastructure:

- Data Integration
- Storage and Compute
- Standards and Ontologies
- Training
- Benefitting from Collective Expertise in Bioinformatics
- Reducing Fragmentation and Aligning National Priorities
- Capacity Building
- Shaping the Direction of ELIXIR
- Preserving National Investments in Life Science Research
- Supporting Local Jobs and Growth
- ELIXIR's Interactions with Industry
- Joint Applications for Additional Funding
- A Stronger Collective Voice

If Australia is to go down the track of joining ELIXIR, then internally we need to develop a coherent and integrated national bioinformatics strategy. There is much to learn from the European experience and as such there is perhaps an opportunity to work with EMBL through EMBL Australia and specifically with the EMBL Australia Bioinformatics Resource (EMBL ABR) and Bioplatforms Australia (BPA) to draw the Australian bioinformatics community together.