Submission
2016 National Research Infrastructure Roadmap
Capability Issues Paper

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Context for Submission

The Australia and New SKA Coordination Committee (ANZSCC) is the mechanism by which the Australian Government, Western Australian Government and New Zealand Government coordinate their respective involvements in the international Square Kilometre Array (SKA) radio astronomy project. Please note, however, that the New Zealand Government has not been involved in the preparation of this Submission.

ANZSCC has made this Submission to ensure the Expert Working Group is informed regarding the status of the SKA project and the potential implications of Australia's involvement; including in relation to the scope of previous funding decisions and possible future funding requirements.

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

The Square Kilometre Array (SKA) may be a prime example of a situation in which an international approach promises scientific and technological returns far in excess of (or not available at all to) a national scale initiative. Amongst the conditions that favoured an international approach in this case:

- Specific geographical requirements that could only be fulfilled in a small number of locations globally;
- Realisation of the project vision requires construction and operation costs which are significantly in excess of what a single nation is able to afford;
- The broad international spread of the scientific, technical and industrial expertise required;
- The high infrastructure threshold for meeting science case requirements – for example meeting the science requirements for the SKA-Low telescope in relation to the 'Epoch of Reionisation' science goal requires a several orders of magnitude increase in capability; and
- The benefits of collaboration at the international, national and local levels, and the significant indirect benefits already flowing from the project (for example, the 150 radio astronomers now working in Western Australia).

Although research capabilities at bigger scales clearly require an international approach, we note the fundamental reliance on national scale capability to underpin any international level endeavour such as the SKA. Indeed the SKA provides a valuable case study of how national scientific institutions (with plenty of support from the university sector) can collaborate to produce an outcome no single institution or nation could deliver.

Australia's involvement in the SKA has been led and sustained by a long term national investment in the CSIRO Australia Telescope National Facility (ATNF) and the university sector. The skills, technology and project management expertise contributed by CSIRO and the universities have been a significant factor in progress to date and will be important in realising the future benefits of Australia's participation. CSIRO's role in the SKA will continue across the domains of project management and engineering, technology development, science and most likely observatory management. Notable in the strong university sector engagement has been the Perth-based International Centre for Radio Astronomy Research (ICRAR), which was established through substantial Western Australian Government investment, and is now a major provider of skills, science expertise and technology development to the SKA; a role we expect it to continue.

CSIRO's role reflects a more general trend in astronomy (and possibly other disciplines), noted in the Decadal Plan for Australian Astronomy, in which the national institutions (including AAO as well as CSIRO) are evolving to support international scale facilities through the training, technology and other support they provide to them. It will be crucial to sustain this national capability into the future to ensure Australia remains able to engage at the international scale.

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

The SKA will be an example of a facility with the critical mass that can be expected to have significant impact in terms of training and skills development outcomes.

The SKA, like other large science infrastructure organisations, is expected to attract the best researchers, engineers, administrators and students from around the world. It will have exacting scientific and technical standards, creating a highly competitive intellectual environment, but also the opportunity and need to collaborate intensively. We would expect this environment to be reflected in training/skill development outcomes, which in turn will lead to favourable career development outcomes and increase the downstream value of the skills of former employees and students.

These opportunities will be not be limited to radio astronomy but will be available across a range of disciplines and skill domains. As one of world's highest data intensive science facilities, the SKA will contribute to the development of a significant big data ecosystem in Australia, potentially providing new pathways for training and skills development in data-intensive science and operations. Other areas include facilities management, renewable energy systems and electronic systems.

A further dimension of the SKA experience worth noting is the opportunity it has provided for the science community and administrators to develop a better appreciation of the issues and processes involved in large scale international collaboration. It may be useful to consider ways in which the expertise gained can be harnessed and used in other contexts.

We also note that (also see Question 4) national research infrastructure (and institutions) are vital contributors to the human capital required to enable engagement with international scale research infrastructure. A significant proportion of the SKA project's design and planning workforce exists due to the investment in Australian organisations such as CSIRO ATNF and ICRAR and the skills development and training they provide.

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

The specific circumstances of the SKA project have led to access arrangements that are a combination of merit and share based mechanisms. The majority of access is reserved for researchers from the SKA member countries, primarily to address the potential for free-riding in relation to membership. However within the membership, access will primarily be determined by merit with time allocation managed by a single time assignment committee. The members have also decided that in the interests of ensuring research excellence that a proportion of telescope time should be available on an 'open skies' basis purely judged by merit.

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

A significant issue faced by the Australian Square Kilometre Array (SKA) precursor telescopes (see **Other Comments** for context), particularly the Murchison Widefield Array (MWA), has been sustaining a level of operations to fully exploit the facilities following initial capital investment to develop national capability. The Expert Working Group may want to consider how the financial model for national capability investment can more effectively address ongoing operational funding.

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?

As a telescope host country, the decommissioning arrangements for the SKA are of particular interest to Australia. The SKA members have agreed to the principle that provision should be made for decommissioning costs and that such costs are the responsibility of the partners. Various mechanisms are being considered, including the establishment of a decommissioning fund that members contribute to over the life of the facility through their contributions towards operational costs, or the inclusion of a legal requirement in the SKA treaty for members to make a one-off contribution once a decision is made to terminate the project and decommission.

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?

The Expert Working Group may want to note that emerging radio astronomy technologies, such as aperture arrays and phased arrays, are playing a key role in the SKA project. These technologies are opening up new parts of the spectrum (such as low frequencies in the 50-350 MHz range) and new observing modes (such as wide field of view/high survey speed) that will have major benefits in terms of the science programs they make possible. A prime example within the science case for the SKA-Low instrument to be based in Australia is the opportunity to observe (potentially for the first time) a theorised cosmological event called the ‘Epoch of Reionisation’, the period when the first stars and galaxies in the Universe are thought to have started emitting radiation.

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?

This response is intended to provide the Expert Working Group with context on Australia’s participation in the Square Kilometre Array (SKA) radio telescope project.

In the National Innovation and Science Agenda (NISA) funding package the Government decided to make explicit provision for two national research infrastructure priority facilities, with one being the SKA. It has been Australian Government policy, in conjunction with the Western Australian Government, to host and actively support the SKA project since 2007.

Status of the SKA project

SKA is entering the final stages of the preparatory phase ahead of the planned start of construction, possibly commencing in late 2018. Key points to note are that:

- The Critical Design Review stage of the design process is expected to be reached in late 2017 or early 2018;
- The SKA member countries (Australia, China, India, Italy, New Zealand, South Africa, Sweden, the Netherlands and the United Kingdom minus Canada which is participating as an observer) are currently negotiating a treaty, the SKA Convention, with the intention of establishing an intergovernmental organisation (IGO) under international law to manage the construction and operational phases of SKA. Current indications are that a threshold number of countries may sign the Convention in time for it to enter into force by the end of 2017;
- Transition from the current project governance arrangement to the IGO (the SKA Observatory) is indicatively expected in late 2017 or early 2018 at which time steps towards construction commencement would formally begin; and
- The precise scope and budget of Phase 1 of SKA construction are still being negotiated between the prospective member states of the IGO – as are the funding contributions that each member will agree to provide.

Current funding provision

The December 2015 NISA package provided an opportunity for the Government to make a funding allocation to support the expected funding requirements of the SKA over the next 10 years.

In NISA the Government provisionally allocated $293.7 million to the SKA. Of this funding:

- $152.6 million is for SKA Phase 1 construction;
- $71.1 million is for 6 years of Australia’s share of operating SKA Phase 1; and
- $70 million to meet Australia’s hosting obligations.

The Government has made the allocation conditional on the satisfactory completion of the SKA treaty negotiation and a satisfactory business case.

Possible future funding requirements

Until the SKA treaty negotiation is finalised and the Government has considered the resulting proposal and made a final decision, the funding requirement for SKA Phase 1 will not be definitively known. The current allocation is an estimate based on the best information available at the time of the NISA process. The final funding requirement may be influenced by the outcomes of both technical processes to determine final design scope and costing of SKA Phase 1 and intergovernmental negotiations regarding the division of funding shares.

A further source of uncertainty relates to which aspects of SKA science production are part of the Observatory and which are to be supported externally. A primary example is the decision that user support and data product access will be within the domain of SKA Regional Centres that are not directly part of the SKA Observatory. Additionally, there will be functions undertaken in SKA Development Centres (i.e. developing technology for future phases of SKA) and Integration and Test Facilities (i.e. to ensure that components are suitable for installation) outside the SKA Observatory itself. Taking maximum advantage of the SKA opportunity may require further investment (from a range of sources) in these areas.

The SKA is being planned to have an approximately 50-year operational lifespan and is expected to be developed in phases. SKA Phase 1 is being planned to be readily expandable towards the “square kilometre” of collecting area envisaged as the full scope of SKA and which would enable the full science case to be pursued. It is not currently known when a future expansion of SKA will occur, or how many phases might be involved in reaching the full scope.

The current provision for Australia’s contribution to the operational budget ends in 2025-26. The Government may need to adjust provision consistent with obligations agreed to in the SKA Convention, should it sign. It should also be noted that there is no provision currently for any subsequent phases of SKA construction.

Data for Research and Discoverability

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?

Australian researchers working with SKA data will rely greatly on the national high performance computing (HPC) and data infrastructure. They will also be part of, and may require access to data infrastructure on an international scale, potentially through a regional network of resources specifically linked to the SKA project. Meeting SKA related research requirements may require a combination of investment in 'bricks-and-mortar' centres such as the Pawsey Centre and on-demand/cloud services available from commercial providers. Addressing these data requirements could provide an opportunity for Australia to develop leading-edge expertise and solutions in cloud/virtualised computing at HPC and big data scales.

Other comments

Importance of Australian SKA precursors

The Expert Working Group may want to note that recent developments linked to Australia's involvement in the SKA project are already making significant contributions to Australia's research infrastructure and science outcomes.

Australia currently hosts two SKA 'precursor' telescopes. SKA precursors are defined as instruments located on the sites hosting the future SKA telescopes which are making major contributions to the development of SKA technology, designs and science programs.

The precursors are:

- The Australian SKA Pathfinder (ASKAP) a 36-dish radio telescope built and operated by CSIRO, which has also been a platform for the development of the Phased Array Feed receiver technology being considered for deployment on subsequent phases of SKA;
- The Murchison Wide-field Array (MWA) telescope – a low frequency aperture array telescope built and operated by an international consortium of universities led by Curtin University. The MWA is playing a vital role in testing and validating SKA1-Low antennas and systems. In addition the MWA/CSIRO operational teams and infrastructure are supporting the deployment of existing and future SKA1-Low verification systems.

Contribution to future 'Big Data' capability

The Expert Working Group may wish to note the potential impact of SKA participation on Australia's future capabilities in the scientific, operational and technology aspects of very-large data sets and processing.

The SKA project will provide one of the largest and most leading edge platforms for big data techniques in the science domain, with key parts of the SKA data infrastructure and operations located in Australia in proximity with the SKA1-Low telescope. The expectation is that SKA will provide numerous local opportunities for industry engagement; training and skills development and synergies with other disciplines.

To provide context on the scale of the SKA big data challenge we note that:

- the Science Data Processor for SKA Phase 1 alone will ingest data at an estimate average rate of 1.5TB/s (across both telescopes);
- the rate of production of science data products has been estimated at 370TB/day or 130 PB/yr, requiring a 100PFlops processing capacity (the current state of the art is 10-15 PFlops).