Key capability requirements for Australian Astronomy (2006-15)

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Background

This report has been prepared as input to the NCRIS process by the National Committee for Astronomy (NCA) based on draft reports from the Working Groups (WGs) for the Australian Astronomy Decadal plan. The Australian Astronomy Decadal Plan process is due to conclude by September 2005, and at this stage little prioritization or phasing of capabilities has been attempted. The NCA recognizes that prioritization is essential, and will begin that process in April on receipt of the final reports from the Working Groups on April 30. However, the NCA understands that a 'long-list' of required capabilities in the astronomy sector would be valuable input to the NCRIS process at this stage and has prepared this report accordingly. The NCA proposes to provide an update to NCRIS on the May/June time scale with initial priorities attached to the capabilities outlined below. A summary of the capabilities is provided at the end of this document.

1. Introduction

Australian Astronomers have been among our nation's most successful scientists. To maintain and build on this success, the WGs consider Australian access to leading international astronomical facilities a high priority over the coming decade. These facilities should cover the radio through optical/infrared wavelengths, as well as facilities for detecting cosmic airshowers and gravitational radiation. Australia's current strong international reputation in astronomy derives to a large extent from our outstanding record of successful innovation in astronomical instrumentation, including optical fibre technology, signal processing, and large instrument engineering. Therefore, these major facilities need to be supported by active technology programs providing leading-edge instruments as well as by continuing to foster the strong research community in Australian universities, CSIRO, and the Anglo-Australian Observatory.

The WGs also consider that strong national facilities play a vital role in Australia's very high international standing in Astronomy. Our national optical and radio observatories are world leaders in technological innovation that has led to Australian scientific leadership in many research areas. Our national facilities also provide exceptional training opportunities for our graduate students and postdoctoral researchers. Support of the following national facilities is essential for the continued success of Australian astronomy.

University-based research capability is also vital to the future of astronomy in Australia. This goal requires a maintaining support and strengthening of University operated astronomical facilities and instrumentation to be a high priority. University based facilities provide astronomical, technical and engineering training at the postgraduate and postdoctoral levels, which is essential for continuing supply of specialists who can maintain and lead internationally competitive research and develop the highest-standard astronomical facilities.

2 Required Capabilities

2.1 International

The maintenance of an internationally competitive capability in radio-astronomy from cm- to mm-wavelengths is a high priority. The highest priority long-term goal in this domain is the International Square Kilometre Array (SKA) project, a radiotelescope 100 times more powerful than any existing facility, currently planned to be built on the 2013-2020 time scale. Australia's natural advantage in freedom from radio-frequency interference provides a unique opportunity to have this international project sited in Australia. To maximise Australia's chances of hosting and participating in the scientific returns (engineering and astronomy) from the SKA, in the coming decade continued investment in the Australia Telescope National Facility (ATNF) and existing University programs such as SKAMP and the University of Tasmania telescopes, together with the development of the radio-quiet Western Australian at Mileura are seen as priorities. The development of the Mileura site includes support for the extended New Technology Demonstrator and the Low Frequency Demonstrator over the period 2006-09, potentially leveraging support in investment in the site from international SKA partners. Together these would provide Australia with the capability to play a leading role in the development of the international SKA pathfinder (10% of the SKA collecting area) on the 2009-12 time scale, seen as necessary to maintain Australia's competitiveness in radio astronomy until the commissioning the full SKA at the end of the next decade.

The maintenance of Australia’s strong research capability in optical/infrared astronomy is a high priority over the coming decade. The essential requirements for achieving this include the continuing operation and strategic upgrading of University-based observatory facilities and the Anglo Australian Telescope. Over the next 5 years, the WGs propose a goal of Australian access to 20% of an 8m facility, achieved by maintaining, through NCRIS, our 6.19% share in the twin Gemini telescopes (i.e. equivalent to a 12.4% share in a single 8m telescope), and augmenting this facility with other 8m-class facilities that have capabilities complementary to Gemini's, including high-resolution spectroscopy, and wide-field imaging and spectroscopy.

To remain internationally competitive, the Australian community must position itself to have access to an Extremely Large Telescope (20-metre diameter+ or equivalent telescope) to be built on the 2008-18 time scale. Such ELTs are presently undergoing preliminary design, and to maximise the technological and scientific returns, the community needs to join into a project in the near term. 20% of such a facility would preserve Australia's historical share of large optical telescopes on the international stage, with a 10% share seen as the minimum useful level of participation. Both the increased 8-metre access and eventual ELT access might be achieved by exploiting the favourable atmospheric conditions in the Australian Antarctic Territory through the initial construction of a 2m-telescope at Dome C.

Over the next decade, a new generation of instruments will open up the region of the electromagnetic spectrum between the radio and optical. Gaining access to these facilities operating through the mm and terahertz regions, including the European-US-Japan Array, ALMA, and smaller telescopes (e.g. APEX, ASTE, NANTEN) is a priority for the community. The WGs propose that the most cost-effective route will be through leverage using the unique scientific capabilities in Australia, both current and proposed.

Such scientific leverage would also help maintain the necessary levels of Australian access to both the current (e.g. Chandra, XMM-Newton, HST and Spitzer) and proposed (James Webb Space Telescope, Herschel, Constellation-X, SOFIA) space-based facilities. This would also apply to the solar system exploration missions (Mars Sample Return, Europa Geophysical Explorer) of the coming decade. Australia also needs to maintain is capability in solar astronomy (a small but internationally successful community) through access to space facilities such as SOHO, the Solar Dynamics Observatory and the Advanced Technology Solar Telescope.

The WGs consider continuing Australia's research capability in Cosmic Airshower Astronomy as a high priority. For Australian astronomers, the essential facilities in this area include the international Pierre Auger Observatory and the Japanese/Australian CANGAROO VHE gamma-ray telescope in South Australia. The requirements are to ensure continuing formal participation in the Auger Observatory, and to ensure long-term support for CANGAROO.

The WGs also recommend the support of Australian involvement in International Gravity Wave Detection Facilities. High priority facilities include the formal participation of Australia in Advanced LIGO (ALIGO) so that Australian astronomers and physicists can access the unique data from this facility. In the longer term, 2013-2018, the WGs see the need for a long baseline full sensitivity gravitational wave detector in Australia to enable the international array to reach maximum sensitivity and sky coverage. In the medium term upgrading of the AIGO test facility in Western Australia to an intermediate baseline, will allow this system to have comparable sensitivity to ALIGO, over a limited frequency range.

In radioastronomy, Very Long Baseline Interferometry (VLBI) is inherently an international activity, and Australia's Southern Hemisphere location gives it a very high value in collaborations with its northern hemisphere partners. Australian astronomers have been pioneers in using high-speed data recording and transmission technology to develop eVLBI, i.e. near-real-time electronic VLBI that will become feasible in the next two to three years, and routine on time scales of five to ten years. It is a high priority to maintain this position of leadership in eVLBI, and to strengthen collaborations with large Northern Hemisphere partners like the European VLBI Network and the US Very Long Baseline Array.

2.2 National Facilities

2.2.1 Optical/Infra-red facilities:

Anglo-Australian Observatory

Australia's national optical observatory is the Anglo-Australian Observatory (AAO) that is expected to become a fully Australian owned and operated facility in about 5 years. The WG considers that full access to the AAO's main facility, the 3.9m Anglo-Australian Telescope (AAT) is essential for Australian astronomers throughout the coming decade (i.e., until 2015). It is also vital that the AAO as an institution be kept running, in order to retain its personnel, intellectual property, and instrument design and construction capability for Australia. The WG considers that the best way to maintain this capacity during the changes anticipated in the coming decade would be for the AAO to become the management institution for all Australia's national optical and infra-red activities, including the Gemini Telescopes, future Extremely Large Telescopes, Antarctic developments and the Virtual Observatory. The AAT itself will need at least one more new instrument over the next decade to maintain its competitiveness ahead of the ELT era.

2.2.2 Radio facilities: Australia Telescope National Facility

Our national radio facilities are run and developed by the CSIRO's Australia Telescope National Facility (ATNF) along with significant University involvement. At centimetre wavelengths the long-term goal is the international SKA. However, in during the SKA development period over the next decade our national facilities will play a vital role in development work and in stimulating the continued training of engineers and astronomers capable of building and using these facilities. The existing ATNF facilities will thus play a dual role in the coming decade, serving as both world-class research facilities for our current scientific programs and as an incubator/test-bed for technology developments associated the SKA project. As such, continued support of the Australia Telescope Compact Array, Parkes and Mopra Telescopes are essential for Australian astronomy.

2.2.3 Theoretical and Computational Astrophysics

The Australian National Institute for Theoretical Astrophysics (ANITA) is a grouping of individuals devoted in particular to theoretical astrophysics research and to the development of theoretical astrophysics as a discipline in Australia. Although not formally a national facility, ANITA does have some of the features of a national facility in the broad view that it takes of the discipline and in the service roles that it undertakes and is planning for the future. The WGs consider that strong support of theoretical astrophysics through an organization such as ANITA is essential to maximise the return we get from our investment in observational facilities.

Astronomers have always been pioneers in using the internet, and the success of future projects will rely heavily on enhanced connectivity, including the SKA if it is to be located in Australia. The WGs recommend Gigabit links (upgraded to 10-100 Gigabits by the end of the decade) connecting Australian astronomical facilities, universities, and our overseas counterparts as having a high priority. Australia is a key player in the international astronomy community, but we are dispersed across the continent, and very distant from most of the international community. The WGs suggest combating this difficulty by placing access grid nodes in each major astronomy centre to provide multi-media conference capabilities to the community for both national and international events.

The explosion in data (Petabyte and above datasets) coming from current and planned astronomy facilities world-wide will present many challenges in the coming decade. The International Virtual Observatory Alliance is a grouping of international partners working to develop the new ITC infrastructure we will need to access and exploit these data resources efficiently. The WGs consider it important that Australia continues to play a role in these developments through support of the Australian Virtual Observatory as a facility that can ensure the integration of Australian major data projects and leverage access to data obtained on international facilities via the International Virtual Observatory.

The WGs also affirm that sustained and significant investment in national and state supercomputing facilities such as APAC and VPAC are critical to the health of Australian astronomy and astrophysics. Together with more dedicated supercomputing facilities to astronomy such as the Swinburne supercluster, these facilities develop capabilities in new ways of data analysis and visualization to maximize the scientific gains from the Australia's astronomical telescopes.

2.3 University facilities

The Australian National University (ANU) astronomy facilities are university-funded, but they also provide substantial amounts of time to national and international users for peer-reviewed research. The ANU facilities also play an essential role in teaching and postgraduate training for the national community, as well as providing a test bed for instrumentation development. For these reasons the WGs strongly support the retention and development of the ANU's Siding Spring Observatory in the next decade as Australia's "small telescope astronomy park". This would include the ANU 2.3m and Skymapper Telescopes as well as the UNSW's APT and ROTSEII telescopes as the minimum core set of facilities. However, this will require additional funding over the coming decade.

The WGs consider as important maintaining capabilities within Universities to build and maintain leading-edge facilities such as the Automated Astrophysical Site Testing Observatory (AASTO) at the South Pole, Automated Patrol Telescope (APT). The WGs also recommend support for new University facilities such as the Dedicated Variability Array. This will provide a capability at radio wavelengths to monitor and following a wide variety of transient sources.

The use of university facilities also provides an avenue for additional training as the need to incorporate research activities into the undergraduate curriculum continues to grow. The role of University-based observatories is also important in maintaining the strong outreach commitments, and the WGs recommend the support of such facilities, which provide educational activities for K-12 students and the general public.

Capability Summary

Optical/IR Capabilities

The following optical/IR capabilities are considered as priorities for the coming decade. These will be required to continue support of the strong optical/IR community within Australian Universities.

- Active participation in an Extremely Large Telescope (ELT) project with a goal of a 20% share of a 20-30m Telescope.
- A substantial increase in Australian access to 8m class Telescopes, with a goal of a 20% share of Gemini (or equivalent).
- Continuing support for the Anglo-Australian Telescope.
- Access to the James Webb Space Telescope.
- Active participation in a major spectroscopic survey facility such as the proposed WFMOS instrument on the Gemini or Subaru Telescopes.
- A large optical/IR telescope constructed in Antarctica, the first stage being a small 2m telescope, followed by a larger 8m (or greater) telescope.
- A strong and active instrumentation technology program.
- University-run telescopes for research, education and outreach

Radio Capabilities

The following radio capabilities are considered priorities for the coming decade. They will support and foster world-class research programs, and also position Australia to play a leading role in the development of new technology for next-generation radio telescopes.

- Active participation at the 10% level in the international Square Kilometre Array (SKA) project, with the aim of having the telescope sited in Australia and playing a leading role in its development.
- In the coming decade, this would be achieved through involvement in the development and use of SKA technology-demonstrator telescopes. This includes the extended New technology Demonstrator (xNTD) based in Western Australia as a forerunner to the SKA pathfinder facility.
- Continued support of the national facility radio telescopes operated by CSIRO (ATCA, Mopra, Parkes, Australian VLBI) and University facilities including the SKA Molonglo Prototype (SKAMP) in NSW and the University of Tasmania radiotelescopes.
- A significant role in the development and use of a large low frequency array sited in a radio quiet region, most likely in Western Australia.

Gravity Wave Capabilities

It is anticipated that astronomical gravity waves will be detected in the next decade, opening up a brand new window on the Universe. The following capabilities would build on Australia's current strength in this area.

- Australian membership of the Advanced LIGO (ALIGO) consortium.
- Construction of a gravity wave telescope in Australia that will work in collaboration with A/LIGO and European antennae to provide optimum sky coverage and maximum sensitivity.

Theoretical/Computational Capabilities

The capabilities required for underpinning research facilities in astronomy are:

- Advanced computational resources, including access to state-of-the-art super-computers (at least one national computer in world top 50).
- Access to National broadband (10-100Gbps) networks
- The set up and maintenance of theoretical centres and institutes to maintain a critical mass in astrophysical theory.

Other Capabilities

- Access to current and future high-energy observatories (X-ray and gamma-ray), e.g. Chandra, XMM-Newton, Cangaroo, Constellation-X, etc.
- Access to mid- and far-IR facilities including Spitzer, Herschel, SOFIA.
- Access to US, European and Japanese-led solar system exploration missions, e.g. Mars Sample Return, Europa Geophysical Explorer
- Access to solar observatories, e.g. SOHO, Solar Dynamics Observatory, Advanced Technology Solar Telescope.