



Astronomy
Australia
Ltd.

Australian National Astronomy Facilities

A guide for decision-makers



Anglo-Australian Telescope
Photo credit: AAO - David Malin



Astronomy Australia Ltd
17 October 2008

Astronomy Australia Ltd's members include all the Australian universities which have a major research capability in radio or optical astronomy, along with the Anglo-Australian Observatory and CSIRO's Australia Telescope National Facility who provide national astronomy infrastructure. Australian university groups also play an important role in infrastructure through the operation of their own facilities, instrument development and student training.

The role of AAL is to co-ordinate matters of national astronomy infrastructure. This requires an ability to extract priorities from the community and effectively manage government funding for research infrastructure.

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Image credit: ANU



1955
74" Telescope - Australia, ACT
Optical

Science Highlight: For many years a unique instrument used to measure chemical abundances in stars.
Australia's Share: 100% - Destroyed in 2003 Mount Stromlo bushfires.

Image credit: CSIRO - Shaun Amy



1988
Australia Telescope Compact Array
Australia, NSW
Radio

Science Highlight: Provided some of the first evidence that long Gamma-Ray Bursts are linked to supernova explosions.
Australia's Share: 100%.

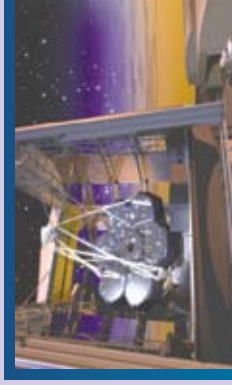
Image credit: Interactive exploration of the ASKAP site. WASP, University of Western Australia



2012
Australian SKA Pathfinder
Australia-WA
Radio

Science Highlight: Will detect a million galaxies in atomic hydrogen to understand galaxy formation and gas evolution in the nearby Universe.
Australia's share: 100%.

Image credit: GMT - Carnegie Observatories



2018
Extremely Large Telescope
Chile
Optical

Science Highlight: Will look back in time at the formation of the first stars and galaxies and see planets around other stars.
Australia's share: currently 10% of GMT project.

1950

1960

1970

1980

1990

2000

2010

2020

2030

1961
Parkes - Australia, NSW
Radio



Science Highlight: Discovered the first double-pulsar allowing astronomers to conduct precise tests on gravitational theories.
Australia's share: 100%.

Image credit: CSIRO - Shaun Amy

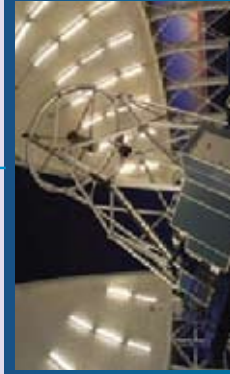
1974
4-m Anglo-Australian Telescope
Australia, NSW
Optical



Science Highlight: The 2dF Galaxy Redshift Survey created the largest 3D map of galaxies in the local Universe and measured the amount of atomic and dark matter.
Australia's share: 50% (original); 100% (2010).

Image credit: AAO - David Malin

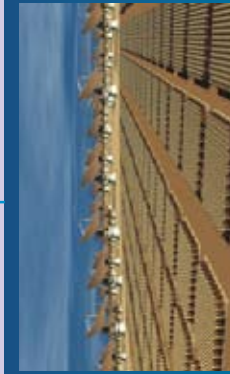
1998
Gemini 8-m Telescopes
Chile & Hawaii
Optical



Science Highlight: Provided some of the first evidence that short Gamma-Ray Bursts are the result of a black hole merging with another black hole or a neutron star.
Australia's share: 6% of each telescope.

Image credit: Gemini Observatory/AURA

2020
Square Kilometer Array
Australia-WA or South Africa
Radio



Science Highlight: Will provide the first detailed maps of the magnetic field of the Milky Way.
Australia's share: To be determined.

Image credit: SKA - Xilo Studios



Executive summary

To gain the scientific and technological benefits from Australia's investment in the path towards the SKA, Australia must maintain a complementary investment in optical telescopes and technologies as laid out in the *Decadal Plan for Australian Astronomy 2006 – 2015*. As the path forward for radio telescopes is clearly defined, this roadmap focuses on investment in optical telescopes.

The issue that needs to be addressed as a matter of urgency is the future governance arrangements and funding for the Anglo-Australian Observatory, for which the current arrangements cease on 30 June 2010. There is extremely strong support within the Australian astronomical community to continue operating the Anglo-Australian Telescope as a national facility at its current level of capability until 2018 and to enhance the Anglo-Australian Observatory's technical capability in optical instrumentation.

A further issue that needs to be addressed is Australia's future access to large optical telescopes. Astronomy Australia Limited endorses the ARC's plan to purchase additional Gemini share to increase Australia's access to 8-metre telescopes in accord with the Decadal Plan. Astronomy Australia Limited and ANU are also working together to position Australia for access to the next generation of extremely large optical telescopes.

The global landscape for large optical telescopes presents options on how to achieve Australia's goals. Therefore the Australian Government should explore joining the European Southern Observatory, which would also provide access to large optical telescopes. This would position Australia to choose between two possibilities for access to large optical telescopes after 2011/12.



Introduction

The *Decadal Plan for Australian Astronomy 2006 – 2015* sets out the astronomy community's consensus on the broad strategy for Australian astronomy. Within the context of the Decadal Plan, Astronomy Australia Ltd (AAL) has recently assessed Australia's path forward for investment in national optical astronomy facilities. That assessment included a review by the Astronomy NCRIS Strategic Options Committee (ANSOC) which has significantly informed the content of this document. This roadmap has been developed by AAL at the instigation of the Department of Innovation, Industry, Science and Research (DIISR). The recommendations in this roadmap were endorsed by the AAL members at their Annual General Meeting on 30 September 2008.

ANSOC and AAL recognise that there has long been synergy between radio and optical observations in the study of exotic objects such as radio galaxies and radio quasars. The new generation of radio telescopes, such as the Australian Square Kilometre Array Pathfinder (ASKAP) and the Square Kilometre Array (SKA), will open up new opportunities for studying the evolution of the ordinary stars and galaxies which have long been the targets of optical telescopes. The synergy between radio and optical observations will be even more important in the future for research in astrophysical and cosmological priority areas: probing the early epochs when galaxies formed, understanding the nature of the dark energy, and using the distribution of galaxies to determine precision values of the cosmological parameters. ASKAP will realise a significant component of its scientific return through synergistic programs undertaken with 4-8-metre class optical telescopes, while many results from the SKA will require synergistic programs undertaken with Extremely Large Telescopes (ELTs).

The next step for radio telescopes is clearly defined and funded: to build ASKAP and continue the operation of the Parkes dish and the Australia Telescope Compact Array. AAL strongly supports this path.

To gain the scientific and technological benefits from this investment in the path towards the SKA, Australia must maintain its complementary investment in optical telescopes and technologies. As the path forward for radio telescopes is clearly defined, this document will focus primarily on how to advance a complementary investment in optical telescopes.

Major astronomy infrastructure has become Big Science and increasingly requires international cooperation to realize its most powerful telescopes. In future, as is already happening with the SKA, astronomical facilities are likely to require organisation at a global level among governments. To maintain engagement in the international arena on the medium and long-term, Australian astronomers therefore foresee a need to explore structural relationships with the relevant overseas organisational players. Several countries participating in the OECD Global Science Forum have realized such a need as well and have begun informal exploration of the modalities for cooperation in the context of SKA and of ELT. Multi-lateral agreements may be required and the cost of participation will likely lead to agreements at government level.

This document represents AAL's current advice to government on likely developments from 2009 to 2018. This roadmap will need to evolve as science advances, events occur and research opportunities arise. The reader is referred to the Decadal Plan for other important topics not dealt with here, such as the evolution of computing infrastructure, optical interferometry, and very long baseline radio interferometry.



Returns from astronomy investments

The last few years have seen major discoveries from new research infrastructure, such as the mapping of the hydrogen gas content of the local Universe and the discovery that massive galaxies have the shortest timescales for turning gas into stars. In the paragraphs below we give some examples of scientific and technical returns expected from new investment. Necessarily, we choose examples and do not attempt to be complete.

Example: New knowledge about the universe

A fundamental astrophysical question for the 21st century is: **How do galaxies form and evolve?**

The understanding of galaxy formation and evolution requires the blueprints for a representative and statistically significant population of galaxies near and far. Each blueprint contains a galaxy's distance, shape, size, chemical composition, mass, abundance and relative fraction of stars, gas and dust. It also contains its environmental status, which includes the number and proximity of neighbouring galaxies and a description of any mergers or interactions between neighbours.

In the Australian context a comprehensive set of blueprints for galaxy formation and evolution will be created over the next five to ten years through two contemporary large area galaxy surveys conducted with the Anglo-Australian Telescope (AAT) and the Australian Square Kilometre Array Pathfinder (ASKAP).

In 2008, an international consortium initiated the Galaxy And Mass Assembly survey using the new AAOmega spectrograph on the AAT. This large optical survey is designed to study galaxy and galaxy group structures to test the current paradigm of galaxy formation and evolution.

While the AAT will provide an enormous amount of information about these galaxies based on the light we receive from stars, it cannot tell us anything about the most fundamental component of galaxies and their formation, atomic hydrogen. ASKAP will determine the amount of hydrogen gas and dark matter tied up in these galaxies.

Together, these radio and optical surveys will provide an extensive set of data much more valuable than the sum of the two parts. This will allow astronomers to measure the distances, shapes, sizes and masses of 250,000 galaxies at a typical distance of 2.4 billion light years. This information will give astronomers a new and more detailed understanding of the formation and evolution of galaxies.



Example: Innovative astronomical instruments

The instruments constructed by the Anglo-Australian Observatory have been the cornerstone of the success of the Anglo-Australian Telescope and UK Schmidt Telescope in recent years, particularly the development of several fibre-fed spectrographs: 2dF, 6dF and AAOmega. As world leaders in this field, the observatory won the contract to design and build the OzPoz positioner for the fibre large array multi-element spectrograph (FLAMES) on the European Southern Observatory's Very Large Telescope (four 8-metre telescopes in Chile) and the Echidna positioner for the Japanese fibre multi-object spectrograph (FMOS) on the Subaru 8-metre telescope in Hawaii.

With NCRIS funding, the Anglo-Australian Observatory is building a fibre-fed high-resolution multi-object echelle spectrograph (HERMES) for fingerprinting millions of stars and unravelling the formation of our Galaxy. The AAO is also continuing Australia's involvement in the current generation of 8m telescopes by carrying out a design study for a multi-million dollar wide-field multi-object spectrograph for the Gemini program.

The instrumentation group of the Research School of Astronomy and Astrophysics at ANU has also contributed significantly to Australia's involvement in current 8-metre telescopes by designing and building two of the primary near-infrared instruments for the Gemini Telescopes: the Near-Infrared integral-Field Spectrograph and the Gemini South Adaptive Optics Imager. ANU also builds instrumentation for its own telescopes at Siding Spring, with the Skymapper Imager recently achieving first light and an integral wide field spectrograph to be commissioned shortly.

The instrumentation group of CSIRO's Australia Telescope National Facility carries out leading-edge development work to keep Australia's radio telescopes at the forefront of radio astronomy. In particular, it pioneered the use of centimetre-wave multi-beam receivers for radioastronomy with the 13-beam 21cm receiver on the Parkes telescope. This receiver has made Parkes a world leader in galactic atomic hydrogen and pulsar studies. The success of this instrument led to a contract to build a 7-beam receiver for the Arecibo 300-metre telescope in Puerto Rico, and a joint project with the Jodrell Bank Observatory to build a 7-beam receiver for methanol surveys.



Example: Wireless technology from radio astronomy

Millimetre Wave Monolithic Integrated Circuits form the core technology embodied in wireless local networking standards. The design of the circuits using semiconductor technologies was developed by CSIRO as a result of their work in radio astronomy. US patent 5,487,069 for a wireless local area network, a peer-to-peer wireless network, a wireless transceiver and a method of transmitting was granted to the CSIRO in January 1993.

Example: Astrophotonics from optical astronomy

Researchers at the Anglo-Australian Observatory and the University of Sydney have applied optical fibres developed for telecommunications to astronomical instruments, significantly extending the capabilities of the original technology.

In 2007 this group of researchers made the first integrated photonic spectrograph – a spectrograph on a single chip. This means that the thousands of fibres from a large telescope can each have a tiny spectrograph. As telescopes grow and instruments become larger and more expensive, this technology offers the possibility of simplifying engineering and containing costs.

Beyond astronomy, this technology innovation has the potential for applications in infrared imaging systems and remote sensing.

Example: Space Science

There are strong links between astronomical instruments and space industry instruments. This led to the spin-off in the 1980s of a space industry company, Auspace, from the Mount Stromlo Observatory of ANU. Investment in an optical instrument capability would also provide the option of expanding into satellite instrumentation.

The on-going Senate inquiry on the space sector, the decadal plan of the space science community, and the recent defence white paper all emphasize the increasing importance of re-establishing an Australian space presence. Developing Australia's capabilities in astronomical instrumentation also positions Australia to excel in space instrumentation in the future.



Radio facilities

Priorities

The strategic priorities for radio astronomy are laid out in *New Horizons: A Decadal Plan for Australian astronomy 2006–2015*:

- Participation in the international Square Kilometre Array project at the 10% level, through the staged development of new radio astronomy infrastructure in Western Australia, with CSIRO as the lead agency. The infrastructure stages will each deliver world-class science.
- Continued operational support of existing Australia Telescope National Facility telescopes (Parkes, Mopra and the Compact Array) but with resources increasingly moved into the development and operation of infrastructure on the SKA roadmap.

Resourcing

The Australian Government will invest over \$100 million in these priorities over the period 2007–12 through:

- The Australian Square Kilometre Array Pathfinder New Policy Program (support for the pathfinder, establishment of the Murchison Radioastronomy Observatory (MRO) and array policy issues).
- The radio astronomy component of the NCRIS investment plan.
- CSIRO Strategic Plan 2007–11 (support for ASKAP and existing infrastructure).

Together, the ASKAP and Murchison Widefield Array (MWA) will prepare the national and international community for the Square Kilometre Array project across a wide scientific, policy, industrial and educational base.

Implementation

CSIRO is the lead organisation for the construction of ASKAP and the management of the Murchison Radioastronomy Observatory. CSIRO will operate ASKAP as part of the National Facility and is currently developing a future operational model with community input for the entire National Facility as required by the resource reprioritisation strategy outlined in the Decadal Plan.

It is envisaged that Australian universities and the proposed International Radio Astronomy Research Centre in Western Australia will be involved in collaborative programs with CSIRO on ASKAP.

A consortium of Australian and international universities and research institutes is proceeding with construction of the MWA.

The joint Commonwealth/WA State Government Australian SKA Coordination Committee provides oversight of and support for policy-related issues in the ASKAP/MWA infrastructure programs and Australia's SKA-related strategy.



Optical facilities

Overview

As recognised by ANSOC, Australia needs a range of optical telescopes of different apertures and capabilities to remain at the forefront of international astronomy.

“Decades of research using optical-infrared facilities have shown that a tiered or layered set of facilities from small to large telescopes is needed to make significant advances in our scientific understanding. The smaller telescopes provide survey capabilities, while the largest telescopes undertake the most challenging observations. The most productive astronomy programmes in leading nations in astronomy are currently centred on the use of a hierarchy of telescopes which incorporates 2-metre, 4-metre and 8-metre class facilities. This will continue into the future, but it is generally expected that the focus will shift towards a suite of larger apertures, 4-metre, 8-metre and 20-30-metre, over the next ten years or so.”

(ANSOC, pp.4-5)

Australia has been especially productive in astronomy at an international level over the past 25 years, largely because it has invested in a hierarchy of telescopes, including 50% ownership of the AAT - one of the five first-generation 4-metre telescopes. Good management, and the continued development of new and innovative instrumentation for the telescope, have made the AAT the most productive of the world's 4m telescopes. However, as the world has invested in the new generation of 8-metre class telescopes –14 over the past decade – Australia has lagged, acquiring the equivalent of just one-eighth of one 8-metre telescope.

The strategic priorities for optical astronomy as laid out in the Decadal Plan are to move the optical telescope hierarchy from the 1-metre, 2-metre and 4-metre telescopes, to 4-metre, 8-metre and 20-metre telescopes. Training the future generation of 8-metre and 20-metre users will continue to be done primarily on the smaller university telescopes and the AAT.

Foundation: AAT & optical instrument capability

We consider that the AAT and an optical instrumentation capability are required for the next decade under any likely scenario.

Recommendation 1:

The Anglo-Australian Telescope should continue to be operated as a national facility at its current level of capability until 2018.

Recommendation 2:

Australia's technical capability in optical astronomy should be enhanced by strengthening the Anglo-Australian Observatory's instrumentation program.



Anglo-Australian Telescope

As Australia will be the sole owner of the AAT after 30 June 2010, Australian investment in the AAT is straightforward, with little associated uncertainty and risk. Keeping the AAT as an Australian national facility for the next 10 years has broad community support. We recommend that AAT operations be kept at the 2007 level, with the facility managed to an expected lifetime of 2018.

“The ANSOC strongly reaffirms the importance of continued operation of the AAT for the next 10 years as a key component of the national optical-infrared astronomy programme. Its accessibility for the next generation of astronomers and the expertise of its staff put it in a position to remain a cornerstone of the national research effort. Although not requesting NCRIS [strategic options] funds, the ANSOC considers the AAT to have great strategic value for the entire Australian community.”

(ANSOC, p.14)

The AAT will continue to be a major contributor to Australian astronomical research for the next decade, serving as a staging ground for Australian astronomical technology and the training of students. Its instrumentation and survey capability are especially well matched to work synergistically with ASKAP.

Optical instrumentation capability

Australia has world leading astronomical instrumentation capability distributed across the AAO, RSAA-ANU and several other Australian universities.

The large-scale and intermittent nature of major optical instrument projects means that a recurrently-funded core of expertise is needed. This core is expanded in times of large projects, transferring their expertise to a larger group of contracted engineers, technicians and scientists. This core group, along with a team of instrumentation scientists, also explores and develops new technologies which can be exploited in the instruments of tomorrow.

As optical telescopes and their instruments become larger and more complex, Australia's distributed network of astronomical instrumentation capability would benefit from focusing on common goals and shared resources. Such a network could benefit from a hub-and-spokes approach, with the AAO providing a national facility hub.

In the 8-metre and 20-metre telescope era, Australia's enviable track record of consistently delivering cutting-edge instrumentation will ensure that Australia can take a leading role in shaping how these huge international facilities are used, despite our relatively small share in the telescopes.



8-metre and 20-metre telescopes

8-metre class telescopes are the state-of-the-art facilities that provide the most sensitive view of the heavens to the world's astronomers. These facilities provide Australian astronomers with a unique opportunity to undertake cutting-edge research, especially when used in concert with the survey capabilities of both the AAT and ASKAP.

Extremely Large Telescopes (ELTs) with a diameter of 20 metres or more will become the front-line facilities of the next decade – looking back to the epoch when the first stars and galaxies emerged from the Big Bang and complementing observations made at radio wavelengths with the SKA.

While the Decadal Plan requirements for optical astronomy infrastructure are clearly specified, the landscape is complicated on both the 8-metre and ELT fronts, where substantial financial, partnership and technical uncertainties exist. We therefore consider two scenarios which could potentially satisfy Australia's 8-metre and ELT requirements as defined in the Decadal Plan.

Scenario 1: Gemini and GMT


In this scenario Australia achieves 10% membership of the Gemini partnership and continues this for the next decade. Australia also becomes a 10% partner in the 25-metre Giant Magellan Telescope (GMT) which is scheduled to complete construction around 2018.

Gemini

Australia's active participation in the Gemini Telescope Partnership via the ARC is our astronomers' primary access to 8-metre telescopes. It remains an essential tool to complement our access to the world-leading survey capabilities of the AAT, ASKAP and university facilities. In galaxy evolution Gemini pushes back further in time than the AAT and in the infrared sees with higher resolution into the structures in which young stars form.

The current International Gemini Agreement ends on 31 December 2012, and re-negotiation of this agreement is scheduled to start soon. There is considerable uncertainty within the partnership about the current instrumentation program, the financial value of partners' shares, the future distribution of partner's shares, and governance. Australia, through the AAO, is leading one of two designs that are in contention to build a US\$60M wide-field spectrograph for Gemini. A decision for the AAO to lead the construction of this instrument, scheduled for 2009, would further increase the value of Gemini for the Australian community.

Australia's investment in a 6.19% fraction of Gemini is substantially less than almost all other developed countries have made in 8-metre telescopes – whether measured on a per capita, per GDP, or per astronomer basis.



“The current limited allotment of 8-metre class nights makes it very difficult to carry out longer-term programs, many of which involve the most important problems in astronomy and cosmology.”

(ANSOC pp 7-8)

For this reason, the ARC has indicated that it is interested in increasing Australia’s share of the two Gemini telescopes to 10%; this would be equivalent to 20% of a single 8-metre telescope. AAL endorses the ARC’s proposed purchase of Gemini share as a suitable way to increase Australia’s access to 8-metre time in accord with the objective of the Decadal Plan.

Recommendation 3:

The Government support ARC’s proposed purchase of an additional 4% share of the Gemini telescopes, on the basis that a realistic price can be negotiated.

Until a 10% share of Gemini is achieved, Australia needs to supplement its access to 8-metre-class telescopes. AAL has therefore arranged for Australia to maintain its access to 15 nights per year on the Magellan telescopes until 2011.

The Magellan telescopes are run by a consortium of US universities and research groups, and provide a wide-ranging suite of instrumentation, largely complementary to the Gemini instrumentation. Magellan offers instruments that are not available on Gemini but are required by several Australian groups. Magellan is an excellent facility to round out Australia’s requirements in 8-metre-class telescopes.

GMT

The foundations are currently being set for the new generation of Extremely Large Telescopes, with three telescopes under active design:

- **The TMT** – a 30-metre telescope – being developed by a consortium of US universities, Canada and possibly Japan;
- **The E-ELT** – a 42-metre telescope – being developed by Europe through ESO; and the
- **GMT** – a 25-metre telescope – being developed by a consortium of US universities, a US research organization, Australia and Korea.

All three telescopes have significant technical risk still to be retired, and none are yet even half-funded. All three telescopes share common technological requirements, and similar financial risks. In the event of consolidation of the projects for financial reasons, existing partners with demonstrated expertise will be in the strongest position to participate in any merged facilities.

Australia is currently a 10% partner in the GMT, whose Detailed Design Phase is scheduled to conclude in 2011. This will retire many of the technical risks to the project and clarify the cost. The financial risk to the project should also be much clearer by 2011.



The ANU has submitted an expression of interest to the Higher Education Endowment Fund (HEEF) to fund 10% share of the GMT build-phase. The ANU's HEEF bid includes funds for Australian-based technological development for the GMT. This is a critical piece of funding to ensure that Australia maximises the benefits of joining an ELT with respect to innovation, training, and astronomical agenda setting. However, to ensure that the Australian community maximises its value from the GMT, this technological development, targeted for RSAA-ANU, needs to be coordinated with the national instrumentation capability.

Recommendation 4:

Provided that an agreement can be negotiated that gives the whole community access consistent with the Decadal Plan's 10% target, AAL endorses ANU's expression of interest in HEEF funding for GMT.

AAL notes that, due to the inherent technical and financial risks associated with the ELT projects, flexibility on when and how the HEEF money could be spent is required.

Scenario 2: ESO

In this scenario Australia's requirements for 8-metre and ELT access after 2012 are provided through membership of the European Southern Observatory (ESO).

The European Southern Observatory (ESO) is formed by an inter-governmental agreement between 13 European countries. It operates a large suite of optical telescopes, including four 8-metre telescopes, and is a major participant in ALMA – a billion dollar millimetre-radio facility being constructed in Chile. In addition, ESO is developing a 42-metre ELT known as the E-ELT. ESO membership fees are based on GDP and, with ESO's current membership, Australia would become approximately a 6% partner of ESO. This equates to a ~24% share of an 8-metre telescope, and a 6% share in an ELT – a roughly comparable capability to the Gemini/GMT scenario.

ESO is a very different way of achieving Australia's astronomical infrastructure requirements. Joining ESO means buying into a whole managed portfolio of astronomical infrastructure, rather than choosing the individual facilities.

ESO offers some advantages compared to the Gemini/GMT scenario.

These include:

- Access to the best-instrumented 8-metre telescopes in the world.
- Further integration of the Australian optical and radio astronomy communities through ESO's participation in ALMA, and potential European leadership of SKA.



But there are also some specific considerations and risks:

- Buying into ESO requires an upfront cost of approximately AU\$130M and it is not clear whether additional funding would be needed to build the E-ELT.
- The Gemini and GMT partnership costs include the full cost of instrumentation; with ESO, Australia would need to fund the labour costs for new instruments in addition to the annual ESO subscription.

Joining ESO requires inter-governmental agreements that, from the evidence of recent history, take several years to negotiate and implement. Given the uncertainty in the global landscape for optical astronomy over the next few years, the useful synergies that exist between ESO and Australia's radio astronomy aspirations, and the value of ensuring two viable options for sufficient Australian access to 8m and 20m class telescopes, AAL makes the following recommendation.

Recommendation 5:

The Australian Government explores the ESO option, so that in 2011/12, two options exist for access to 8-metre and 20-metre class telescopes.

Opportunities in Antarctic Astronomy

Extensive testing indicates that high sites in Antarctica can provide the best seeing conditions on the planet, offering a factor of two improvement over the best alternative sites. The low temperatures and relatively stable low-velocity wind and turbulence patterns are ideal for wide-field infrared surveys in particular. The known best sites, at Dome A and Dome C are within the Australian Antarctic Territory. The French/Italian Concordia Station is at Dome C and an Australian team has contributed to site-testing campaigns there. The team has also installed remotely-controlled facilities at Dome A, in collaboration with the Chinese, US and UK.

Recommendation 6:

Australia should continue to play a leading role in exploring the unique observing conditions in Antarctica. AAL has tasked its Australian Antarctic Astronomy Advisory Committee to develop and propose a program to enhance international relationships and collaboration opportunities, to progress the Antarctic opportunity.

Australia should build upon its demonstrated strengths in the Antarctic region, in terms of established resources including three operating coastal bases with sea link, air strip and air services, along with Australia's experience and commitment to many branches of science over many decades, including some 15 years in the case of astronomy.

As an indication of costs, the conceptual design study for a 2.5-metre telescope to be sited at Dome C estimated the cost of the telescope, optics, dome, tower and air-conditioning at AU\$31M.



Summary: The path forward

Recommendations

The issue that needs to be addressed as a matter of urgency is the future governance arrangements and funding for the Anglo-Australian Observatory, for which the current arrangements cease on 30 June 2010. AAL understands that the AAO and the Department of Innovation are developing budgets and options for the future of the AAO. In that context AAL recommends that:

Recommendation 1:

The Anglo-Australian Telescope should continue to be operated as a national facility at its current level of capability until 2018.

Recommendation 2:

Australia's technical capability in optical astronomy should be enhanced by strengthening the Anglo-Australian Observatory's instrumentation program.

The issue that needs to be addressed by 2011 is Australia's future access to large optical telescopes as specified in the Decadal Plan:

Recommendation 3:

The Government support ARC's proposed purchase of an additional 4% share of the Gemini telescopes, on the basis that a realistic price can be negotiated.

Recommendation 4:

Provided that an agreement can be negotiated that gives the whole community access consistent with the Decadal Plan's 10% target, AAL endorses ANU's expression of interest in HEEF funding for GMT.

Recommendation 5:

The Australian Government explores the ESO option, so that in 2011/12, two options exist for access to 8-metre and 20-metre class telescopes.

Recommendation 6:

Australia should continue to play a leading role in exploring the unique observing conditions in Antarctica. AAL has tasked its Australian Antarctic Astronomy Advisory Committee to develop and propose a program to enhance international relationships and collaboration opportunities, to progress the Antarctic opportunity.



Milestones

As the following milestones occur it will be necessary to update this roadmap to reflect the changing international landscape for astronomy infrastructure.

2009:

- Governance model and funding commitments put in place for AAO.
- ARC negotiations to increase Gemini Partner share.
- Decision for funding ANU GMT HEEF grant.
- Begin negotiations with ESO for decision in 2012.
- Develop a new strategic plan for Antarctic astronomy.

2011:

- GMT DDP completes.
- Magellan time agreement lapses.
- NCRIS program lapses.
- Re-negotiation of the Gemini Partnership agreement.

2012:

- Decision between GMT/Gemini and ESO.
- Site decision for SKA expected.