Astronomy Australia Ltd.

19th September 2008

To: The Australian astronomical community

Dear Friends,

As discussed at the ASA meeting in Perth in July, Astronomy Australia Ltd (AAL) had commissioned an external panel including Garth Illingworth, Robert Williams and Malcolm Longair to review the Australian engagement with various optical-infrared facilities, existing and proposed. The report from this Astronomy NCRIS Strategic Options Committee was released today on the AAL website.

Comment as to matters of fact is now being sought from AAL's advisory committees prior to AAL reaching a decision on the recommendations in this report. AAL will then submit its recommendations to the Australian Government.

The AAL Board will meet on 29th September and the AAL Board will also seek comments on 30th September from AAL's member representatives at our Annual General Meeting.

I will of course keep you updated on the outcomes of these two meetings.

Yours sincerely,

Dr Martin Cole,

Chair, AAL

PO Box 2100, Hawthorn, VIC 3122
Telephone: +61 3 9214 5854; Fax: +61 3 9214 4396
ACN: 124 973 584; ABN: 19 124 973 584
www.astronomyaustralia.org.au

Astronomy NCRIS Strategic Options Committee Report to the Board of Astronomy Australia Ltd.

Executive Summary

The Astronomy NCRIS Strategic Options Committee (ANSOC) was set up as a special purpose committee to make recommendations regarding the options for optical-infrared astronomy incorporated in the NCRIS Investment Plan. In addition, the Committee was charged with the specific task of making recommendations about the use of the Strategic Options Fund. The proposals for these funds requested $12.035M in total; $5.285M is available from the Strategic Options Fund. Our findings and recommendations are:

- The Committee members remain deeply impressed by the productivity and originality of the Australian astronomy community, and reaffirm Australia's world-leading role in astronomical research.
- Worldwide interest in Extremely Large Telescopes (ELTs) among the astronomical communities of all nations with significant investments in optical-infrared astronomy indicates the importance of these telescopes for carrying out the most challenging and exciting observations in these wavebands.
- Synergistic observations will be needed in the future to maximize the scientific return from the new generation of large radio facilities. Synergy between optical-infrared and radio facilities will play a key role in the future with the next generation of facilities like ASKAP and SKA.
- The ANSOC are convinced that there is a world-leading programme of survey astronomy to be carried out by the AAT over the next ten years, until late into the next decade, and that funding should be continued at roughly its present level through that period. The proposals contained in the document "The Anglo-Australian Telescope – Case to ANSOC" are fully endorsed by the Committee and recommended for full funding for a period of ten years through the routes outlined in that document.
- The ANSOC agrees that 8-m class telescopes will remain the premier ground-based research facilities in optical-infrared astronomy for at least the next decade, and will play a central role in the subsequent ELT era. The ANSOC agrees with the recommendation of the "New Horizons" Decadal Plan that providing an equivalent of 20% of one 8-m telescope is vital to the continued development of Australian optical-infrared astronomy. We applaud the initiative of the Australian Research Council which has already announced its intention of supporting a 4% increased share in the Gemini partnership. We recommend that US$1.72M be provided for a continuation of the current Magellan programme.
- The ANSOC agreed that participation in an ELT was necessary for any astronomical community whose vision and goal was to remain at the cutting edge of scientific endeavours in the next decade and beyond. The ANSOC consider that a 10% share in the partnership is a minimum level for Australia to be a significant, effective and influential player in an ELT.

The ANSOC considers the funding of the design and development phase (DDP) of the GMT to be of the highest priority. We recommend that US$2.33M be invested in the GMT-DDP programme, bringing the total Australian share to 10% over the period until 2011.

- Australia should play the leading role in exploring the unique observing capabilities of Antarctica, given the relative proximity of Antarctica to Australia.
- The ANSOC believes that the scale of the PILOT project is no longer one which could be appropriately managed and operated as a University-scale project, but rather should be undertaken as a major national initiative with the full involvement of international partners. In our view, the project has not yet reached the level of maturity at which we would be able to recommend that it go forward. To enable a viable project at some time in the future, we recommend a number of essential research and development steps needed to achieve the level of confidence to undertake such a project.
- The ANSOC considers that public outreach, education and involvement in the achievements of Australian Astronomy should be an essential component of the astronomical programme. AAL should be encouraged to work with the Australian research community to develop plans for education and outreach that will make the most effective use of the resources in an Australian context.
- The Committee emphasises the necessity of making adequate provision for the operating costs for the facilities proposed in the Decadal Plan for Astronomy. It is essential that the planning for major new investments take full account of the necessary operating costs or the full scientific capability of the investments will not be realized.

In summary, we recommend US$1.72M for continuation of the current Magellan programme and US$2.33M for a 5% share of the GMT-DDP programme, for a total of AU$5.07M (using an exchange rate of 0.8USD = 1AUD). The residual funding from the NCRIS Strategic Options $5.285M should be retained initially to deal with possible currency exchange rate changes, and applied, if funds remain, to the support of the GMT project within Australia.

Introduction

The Astronomy NCRIS[1] Strategic Options Committee (ANSOC) was set up as a special purpose committee to make recommendations regarding the options for optical-infrared astronomy incorporated in the NCRIS Investment Plan. This Plan reflected the aspirations of the Australian astronomical community as set out in the Decadal Plan for Australian Astronomy 2006-2015. In addition, the Committee was charged with the specific task of making recommendations about the use of the Strategic Options Fund in the light of the fullest possible consideration of the overall strategic position of Australian

[1] National Collaborative Research Infrastructure Strategy (NCRIS) of the Department of Innovation, Industry, Science and Research of the Australian Government.

astronomy. The ANSOC recommendations are to the Board of Astronomy Australia Ltd (AAL).

The majority of the ANSOC were international members who provided an independent assessment within a global astronomical context. The ANSOC also contained two members of the AAL Board who provided guidance and context on the questions and issues relating to science policy and science support within Australia. The members of the ANSOC were:

- Prof. Michael Barber (Chair), AAL Board;
- Mr David Warren, AAL Board;
- Prof. Garth Illingworth, University of California Observatories/Lick Observatory;
- Dr. Robert Williams, Space Telescope Science Institute;
- Prof. Malcolm Longair, University of Cambridge.

The Committee met in Sydney, Canberra and Melbourne during the period 1st to 5th September 2008 and discussed each of the proposals for NCRIS funding with the leaders and key members of the proposing teams or groups. All the meetings were attended and supported by Mr Mark McAuley, Chief Operating Officer of AAL, who provided advice regarding the structural framework within which AAL operates, and Dr Lisa Germany of AAL, who provided valuable support for the committee by noting key points for subsequent discussion. Kate Farmer provided excellent help with logistic support. We thank them all for their assistance. We also received excellent input from the proponents of the four projects under review. We thank them for their thorough and comprehensive reports and for their thoughtful and frank responses to our questions.

The NCRIS process has provided funds to support identified strategic options, consistent with the long-term plan for astronomy. The available funds could not support all the proposals and so the Australian astronomical community was faced with difficult choices. To assist this process, the advice of the external members of the ANSOC was sought with a view to obtaining impartial recommendations in the light of their extensive national and international experience in the development and operation of large astronomical facilities and programmes.

Terms of Reference

The terms of reference are publicly available and can be viewed at http://astronomyaustralia.org.au/ansoc_TOR.html. The specific terms of reference for the ANSOC are listed in the attached Appendix A.

Background

The charge to the ANSOC was directed explicitly at recommendations for the allocation of the balance of uncommitted NCRIS strategic funding, which amounted to AU$5.285M. Three projects were identified as potential recipients of these funds: 8-m class telescopes, the Giant Magellan Telescope Design and Development Phase (GMT-DDP) and the Pathfinder for an

International Large Optical Telescope (PILOT). A fourth project, continued operation of the Anglo-Australian Telescope (AAT), was identified as of strategic importance, but no funding was requested for this activity from these funds.

While the primary responsibility of the Committee was to recommend the allocation of these funds, it was also recognized by the committee, by AAL, and by the proposers that such near-term choices have long-term strategic implications for the future structure and development of Australian astronomy. The ANSOC therefore spent time and effort in understanding the broader strategic framework for Australian astronomy, as reflected in the "New Horizons" Decadal Plan and the NCRIS proposals, as well as government and community actions since these documents were produced.

The ANSOC recognized the challenge it faced, since the submissions totalled AU$12.035M. Additional uncertainty arose because over half of the requests were in US dollars. An exchange rate of 0.8 AU$ to the US$ has been assumed, consistent with recent trends. Thus, less than half of the requests, amounting to about 44% of the total at the above exchange rate, could be accommodated.

Strategic Future

The strategic framework for the discussions and recommendations of the ANSOC was informed by the collective international scientific and policy experience of its members, as well as their understanding of likely developments of major projects on a national and international scale. The strength of the Australian community in radio and optical-infrared astronomy, based on their world-class contributions to these disciplines, also played a major role in the Committee's assessments. The Committee members remain deeply impressed by the productivity and originality of the Australian astronomy community, and reaffirm Australia's world-leading role in astronomical research. Ensuring the continuation of this hard-won reputation for scientific productivity in astronomy, and enhancing it, was at the forefront of the Committee's strategic thinking. In this context, the radio community will be well-served by the national support for implementing the Square Kilometre Array (SKA), and particularly in the coming decade with the development of scientifically-productive precursors such as the Australian SKA Pathfinder (ASKAP).

The future direction for the optical-infrared community is less clear. The four projects under review, the AAT, 8-m telescopes, the GMT-DDP and PILOT, all have the potential to be major contributors to future cutting-edge research in optical-infrared astronomy in Australia. Worldwide interest in Extremely Large Telescopes (ELTs) among the astronomical communities of all nations with significant investments in optical-infrared astronomy indicates the importance of these telescopes for carrying out the most challenging and exciting observations in these wavebands.

In addition, 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-m, 4-m and 8-m 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-m, 8-m and 20-30-m, over the next ten years or so.

Synergy

Optical-infrared facilities have enormous scientific value in their own right. An additional factor in the committee's deliberations was, however, the recognition of the increasing importance of synergy between facilities at very different wavelengths. This has been a key development in astronomy, particularly in the last decade, driven in particular by space telescopes such as the Hubble Space Telescope, the Einstein and XMM Newton X-ray observatories and infrared facilities such as the Spitzer Space Telescope. Observations made by one facility, such as images from the Hubble Space Telescope, have led to demand for observations with other facilities, such as spectroscopic observations with 8-m class telescopes, such as the Gemini and Magellan Telescopes, to realize the full scientific return. Another example concerns the holes in the distribution of hot gas in X-ray images of clusters of galaxies which are inflated by clouds of high energy particles that are observed in the radio waveband.

Such synergistic observations will be needed in the future to maximize the scientific return from the new generation of large radio facilities. There has always been synergy between radio and optical-infrared observations in the study of exotic objects such as radio galaxies and radio quasars and this will undoubtedly continue. The big difference with the new generation of radio astronomy facilities such as ASKAP, and even more so with the SKA, is that they will open up new opportunities for studying the evolution of the ordinary material of the universe, the stars and galaxies, that have long been the principal targets of optical-infrared facilities. This synergy will be important for research in a much wider range of the key astrophysical and cosmological priority areas – for example, probing the early epochs when galaxies first formed, understanding better the nature of the dark energy and using the large scale structure of the galaxy distribution to determine precision values of the cosmological parameters. Facilities to be completed in the near to medium term, such as Atacama Large Millimetre Array (ALMA) and ASKAP, will realize much of their scientific return through synergistic programs undertaken with 4-8-m class telescopes, while in many areas results from the SKA will require synergistic programs undertaken with ELTs.

Given the national commitment to ASKAP and SKA, the importance of fully realizing its investment in these facilities for Australian astronomy was a factor in the Committee's thinking regarding the strategic framework. Australian astronomers need to have access to cutting-edge optical-infrared facilities to ensure that the credit for discoveries made by follow-up observations accrues to Australia. It would be unfortunate, to say the least, if observations carried out on major radio facilities in Australia by Australian astronomers resulted in publications and credit for these discoveries being attributed to optical-infrared

astronomers from other countries with guaranteed access to 8-m telescopes and ELTs, which would be unavailable to Australian astronomers.

Individual Proposals

Continued Operation of the AAT

Proposal

The Anglo-Australian Telescope (AAT) has played a crucial role in bringing Australian astronomy to its current forefront position in astronomical research on a worldwide basis. The strategic thinking behind the role that the 4-m AAT can play in the era of 8-10 metre telescopes has been exemplary in that the telescope has been specialized to undertake multi-object spectroscopic surveys over a wide-field, a unique and very important and productive astronomical capability. The scientific pay-back for that investment has been enormous. The AAO 2dF survey has had a huge impact on cosmology. This investment in the necessary advanced technology to undertake such surveys has resulted in an expert team of technologists, instrumentalists, software specialists and astronomers who are capable to extracting the maximum amount of information from these huge data sets. These capabilities must be maintained for the benefit of the next generation of large astronomical facilities. We fully endorse the claims for excellence made in the case presented to the ANSOC for continued operation of the AAT.

The issue facing the ANSOC was the role of the 4-m AAT during the era of the 8-m telescopes and the coming generation of ELTs. The Director and his colleagues have put together an excellent plan for new investment in the AAT over the next five years which builds upon the technical strengths of the AAO and is very well matched to future opportunities to make a major impact on the world astronomical scene. These plans are fully consistent with the recommendations of the “New Horizons” Decadal Plan and the AAO Review Report. A key component is a new instrument HERMES, a multi-object high spectral resolution spectrograph with resolution R = 30,000 and 400 fibre feeds. Its primary goal will be the elucidation of the evolutionary history of the stars in our own Galaxy, what is often referred to as Galactic archaeology. This facility is very well matched to the expertise of Australian astronomers and also to future complementary projects, such as the GAIA project of the European Space Agency, which will provide a map of billions of stars in the Galaxy. GAIA will not, however, be able to carry out the detailed characterization of the different populations of stars in the Galaxy. The enhanced AAT will provide a unique wide-field high-resolution facility for astronomy that will attract the strong scientific interest of the international community.

Evaluation

We are convinced that there is a world-leading programme of survey astronomy to be carried out by the AAT over the next ten years, until late into the next decade, and that funding should be continued at roughly its present level through that period. The many benefits in the training of students, maintenance of expertise in instrumentation and software, the fostering of a

domestic programme at the cutting edge of international science and the unambiguous evidence these provide for the outstanding capabilities of the Australian community, are fully endorsed by the Committee.

The future beyond the period of the Decadal Plan is likely to see a move towards a different mode of operation, possibly involving the telescope becoming a University-owned facility operated on much reduced operating costs with a yet more focussed programme and no longer the responsibility of Government. The exact role depends upon a number of intangibles, including the rate at which the ELTs become a reality and the success of the Australian community in acquiring additional 8-m observing time.

In summary, the proposals contained in the document “The Anglo-Australian Telescope – Case to ANSOC” are fully endorsed by the Committee and recommended for full funding for a period of ten years through the routes outlined in that document.

Additional Access to 8-m Class Telescopes

Proposal

8-m telescopes are currently the gold standard of the world’s ground-based optical-infrared facilities. They require significant resources and therefore are mostly constructed by only the largest countries. Access to these telescopes is essential if Australian astronomers are to remain competitive with the rest of the world. NCRIS Strategic Options funds are requested to increase community access to world-leading 8-m class telescope facilities. A multi-facility approach is proposed that seeks an increased partnership share in Gemini funded by the ARC, additional time on the Gemini Telescopes funded through the ANSOC process, and continued access to the complementary facilities of the Magellan telescopes through ANSOC funding. The proposed package would increase the community’s access to 8-m class telescopes to the level of 28% of one 8-m telescope until the end of 2011. These proposals would satisfy the recommendation of the Decadal Plan that the equivalent of at least 20% of an 8-m should be available to the Australian community. The funds requested from the ANSOC process totalled US$3.82M.

The Australian Gemini Steering Committee (AGSC) has argued that Australian access to 8-m telescopes should increase by a factor of two over the current level of about 12% of an 8-m telescope if the Australian research community is to exploit effectively the capabilities of such facilities. Their proposed strategy involves additional access to three 8-m class facilities, Gemini, Magellan and ESO Very Large Telescope. We applaud the initiative of the Australian Research Council (ARC) which has already announced its intention of supporting a 4% increased share in the Gemini partnership, representing 22 nights per year. The proposal to the ANSOC requests funding to purchase 15 nights per year on the Magellan 6.5m telescopes at a cost of US$1.725M, and a further 12 nights per year on the Gemini 8-m telescopes at a cost of US$2.1M, both until the end of 2011. The justification for these requests is that this number of nights is needed by Australian astronomers both to maintain forefront research programs, and to make more observing time available for programs requiring a larger number of nights. The current limited allotment of 8-m class nights makes it very difficult to carry out longer-

term programs, many of which involve the most important problems in astronomy and cosmology, on these facilities.

Evaluation

The ANSOC agrees that 8-m class telescopes will remain the premier ground-based research facilities in optical-infrared astronomy for at least the next decade and will play a central role in the subsequent ELT era. They are essential for competitive research in most of the exciting areas of astronomy. Dependable long-term access to 8-m-class telescopes at a level appropriate to the size of the community is essential if Australia is to maintain its competitiveness in international astronomy and to reap the full potential of its radio facilities through the types of synergistic programmes mentioned above.

There are two ways by which Australia gains access to 8-m facilities: it can buy into a partnership, as it has with Gemini, resulting in full participation in the development and operation of the facility, including its instrumentation and policies. Alternatively, Australia can purchase nights on telescopes from existing partnerships and observatories. The former is more expensive but provides more benefit to Australian astronomy because the astronomers then sit at the same table as the world's most creative scientists where the important new ideas and concepts are formulated. ARC funding for increased participation in the Gemini Observatories accomplishes this, although Australian influence is somewhat diminished by its minor share in a partnership whose primary partner is the dominant U.S. community. The increased share of Gemini made possible by ARC funding is therefore an important advance, but it does not provide all the 8-m time necessary to meet the needs of the Australian community.

The ANSOC agrees with the recommendation of the "New Horizons" Decadal Plan that providing an equivalent of 20% of one 8-m telescope is vital to the continued development of Australian optical-infrared astronomy. This percentage can be fully justified in the light of the recent productivity of Australian astronomers who have used these facilities, measured by both the number of papers and their citations. The purchase of additional nights on 8-m class telescopes is therefore one of our strongest recommendations. Given the ARC's commitment to an increased share in Gemini, we agree with the AGSC assessment that access to the Magellan facilities is the appropriate priority at this time, and complements those of Gemini because of the Magellan telescopes' suite of instruments. We recommend that US$1.72M be provided for a continuation of the current Magellan programme. This would enable 15 6.5-m nights per year to be purchased on the Magellan telescopes until the end of 2011, half of the contribution being in cash and the other half through the funding of two Australian Fellows resident in Chile.

The ANSOC was interested to hear from a number of leading Australian astronomers that consideration is being given to the period late in the next decade and beyond, when the AAT would be retired or converted into a much more specialized facility. The Committee agrees that, on roughly a 10 year timescale, 8-m telescopes will become the "workhorses" of optical-infrared astronomy, largely replacing the use of general-purpose 4-m class telescopes. The view that planning is needed for a larger Australian share of

8-m class telescopes, at the 50% level or more in the long term, was agreed by the Committee to be an entirely reasonable strategy.

Investment in the Giant Magellan Telescope Design and Development Phase (GMT-DDP)

Proposal

The Australian Giant Magellan Telescope Advisory Group (AGMTAC) and the Australian Giant Magellan Telescope Project Office (AGMTPO) proposed that US$2.33M be allocated from the NCRIS Strategic Options fund to provide a 5% Australian national share in the GMT Design and Development Phase, as well as AU$0.944M to enhance and broaden participation in the GMT project within the Australian community.

The Australian National University (ANU) made a financial commitment to GMT in 2007 that gave ANU a seat on the GMT Board and the means of participating in the DDP. During this phase, the GMT will evolve from the conceptual phase to a more detailed and clearly defined project. This is a crucial phase of the project since decisions made during this phase will largely define the performance characteristics and capabilities of the final design of the telescope. The interest of the Australian astronomy community in being a significant player in an Extremely Large Telescope (ELT), as expressed in the "New Horizons" Decadal Plan and in the NCRIS proposal, led to the proposal to match the ANU's 5% contribution, thereby ensuring a role for Australia at the 10% level. Participation at the 10% level was argued to be vital as the minimum that would be necessary to influence and impact decisions made on the telescope characteristics and capabilities to match Australian aspirations.

Evaluation

The ANSOC agreed with the Australian optical-infrared community's view that participation in an ELT was necessary for any astronomical community whose vision and goal was to remain at the cutting edge of scientific endeavours in the next decade and beyond. As noted above, the planned investment in radio facilities on the scale of SKA will also be leveraged by having a strong Australian optical-infrared community with access to the world's largest telescopes. This will ensure that the scientific discoveries made with observations from joint programs on SKA and ELTs will be carried out, and seen to be carried out, by Australian astronomers.

The committee also discussed the GMT as the ELT project of choice for Australia. Three projects are currently under conceptual development, the GMT and Thirty Metre Telescope (TMT) in the USA, and the European Extremely Large Telescope (E-ELT) in Europe. All three are still at an early stage of development. The committee agreed with the view, expressed through the submissions and our discussions with the proponents and others, that the GMT project is currently best-matched to Australian interests and observational approaches in terms of scale, partnership structure, partner science interests and goals, and operational models. Choices may be made over the coming years that may change the landscape, but early investment in technological studies will be of the greatest value to future involvement in any of the ELT projects. The Committee agrees with the view that sitting on the

sidelines is not appropriate at this time – the Australian community must be a full partner at an early stage to demonstrate their serious commitment to the success of the ELT project.

The committee heard that the experience with 8-m telescopes has reinforced the view that the returns to the Australian astronomy community will be optimized by being an active player during the project definition phase. In addition to being an active player, the committee concurred with the view that, to be a significant player, comparable to other members, Australia should have a minimum 10% share. The ANU share of 5% of the GMT project gives them one Board member. The committee is therefore strongly supportive of the request for the funding of a national 5% share of the GMT-DDP. In particular the committee felt that it was crucial that the level of funding from NCRIS be kept at, or above, 5% to ensure an additional seat on the GMT Board during the critical DDP period in addition to that already taken up by the ANU. We give higher priority to funding the GMT-DDP programme of the ELT/GMT submission and lower priority to enhancing and broadening participation in the GMT project within the Australian community.

Pathfinder for an International Large Optical Telescope (PILOT)

Proposal

The PILOT proposal is a new and imaginative initiative to locate a 2.5-m optical-infrared telescope at a high site, known as Dome C, on the Antarctic continent. The environmental conditions for astronomical observations have been found to be very challenging but the atmospheric characteristics appear to be outstanding, quite possibly the best in the world for optical-infrared observing.

There are, however, numerous challenges to be addressed and resolved before astronomers can fully capitalize upon the excellence of the Dome C site. These include the logistics of operating on a remote and difficult site, the need to ensure the reliable operation of a 2.5-m telescope at the diffraction limit over long periods and the importance of solving the problem of the very high humidity at Dome C. The proponents of the programme have proposed solutions to these problems and they are of the view that none of these are show-stoppers. The Dome C site is being operated through a collaboration between French and Italian scientists who have carried out extensive programmes of site characterisation. The Australian astronomers have been welcomed as guest scientists. There is also strong scientific interest by Chinese astronomers and others who are already operating a platform of small telescopes at Dome A (the PLATeau Observatory – PLATO – project).

The international collaborators are not yet committed to the construction of a telescope at Dome C and have not agreed to project plans to do so. The ANSOC considers international collaboration to be essential in order to optimise the prospects for the future construction and operation of such a telescope. It is the view of the proponents that Australia should play the leading role in exploiting the unique observing capabilities of Antarctica and

we are sympathetic to that view, given the relative proximity of the Dome C observing site to Australia.

Evaluation

We were made aware of the fact that, what had originally been conceived of as a modest programme of development, construction and operation of a 2.5-m telescope had evolved into a very much larger project with an estimated full-cycle cost of $AU129M. We were informed that there is significant uncertainty in this figure and no contingency. Given the lack of contingency, the Committee is of the view that it is quite likely that the final costs will be significantly higher, recognising that, at this stage of similar challenging projects, overall contingencies of the order of 30% are commonly seen as appropriate. The ANSOC also believes that the scale of the project is no longer one which could be appropriately managed and operated as a University-scale project, but rather should be undertaken as a major national initiative with the full involvement of international partners. In our view, the project has not yet reached the level of maturity at which we would be able to recommend that it go forward.

The committee also discussed each of the NCRIS funding requests in the context of its synergistic value with Australian investment in ASKAP and the expected investment in the SKA. In the case of PILOT, its synergistic contributions are not as apparent as would arise from capitalising on the capabilities, in particular the spectroscopic capabilities, of the 8-m telescopes and an ELT in support of future Australian radio facilities.

To enable a viable project at some time in the future, we would recommend a number of essential research and development steps needed to achieve the level of confidence to undertake such a project.

a) Experience with the operation of small telescopes and the ability to deal with the humidity and other environmental problems are priorities.

b) It is essential that international collaboration be established with other partners to facilitate the project. Serious discussions should be held with European and Chinese astronomers, who have a presence in Antarctica and have shown strong interest in building telescopes there.

c) There is a need to define more reliably the construction and operations costs of an Antarctic telescope, including adequate contingency, as a national and international facility, taking into account potential contributions from international partners.

d) Strong project management will be mandatory to enable a future project of this complexity to go ahead.

In summary, we agree with the perspective that there is a case to be made for capitalizing upon the unique qualities of Antarctica as an observing site. The issues for the Committee are what it will realistically cost to achieve that goal, to establish that it is clearly cost effective relative to the other options for astronomy, and to clarify its role relative to other Australian and international investments.

Other Considerations

Education and Public Outreach

The ANSOC considers that public outreach, education and involvement in the achievements of Australian Astronomy should be an essential component of the astronomical programme. This is a key component of enhancing the appreciation of science by the public, particularly in engaging young people in the physical sciences. There are many problems with the education of young people in the physical and exact sciences which are of the greatest concern to many of us – the flight from the exact and mathematical sciences, the need to increase the numbers of teachers qualified to teach disciplines such as physics, mathematics and other physical sciences, the need to provide industry with technically qualified students and the need to ensure that the present generation of young people entering primary school will be those who will exploit facilities such as the SKA and the ELTs. These are world-wide concerns and proactive steps need to be taken to reverse what many of us perceive as a catastrophic decline in the numbers of technically and scientifically-qualified high school students.

Astronomical outreach has a key role to play, not only in reversing these trends, but also in maintaining public interest and support for the astronomical programme. The scale of future funding requires buy-in by the general public who have a right to be informed about the successes of their investments in astronomy and have a strong interest in supporting Australian scientists in attaining their scientific aspirations. A spectacular example of the value and effectiveness of outreach has been the success of the Hubble Space Telescope public outreach programme. The Hubble Space Telescope has left an indelible imprint upon the imaginations of the global public. We strongly encourage consideration of outreach at the level of astronomical organizations such as AAO, and also the provision of opportunities for individual researchers through their grants.

We recommend the development of a public outreach programme. AAL should be encouraged to work with the Australian research community to develop plans for education and outreach that will make the most effective use of the resources in an Australian context. Given the extensive efforts in the UK and the USA, the experience in those communities could provide insights into some approaches that might be most effectively adapted to the Australian situation. The value in beginning this effort now is the opportunity to take full advantage of the upcoming International Year of Astronomy in 2009. There will be many opportunities during the International Year of Astronomy, to highlight the remarkable achievements of astronomy in creating a compelling picture of the origin and evolution of all aspects of the Universe we live in.

Synergy between radio and optical-infrared facilities

Australian astronomers and astrophysicists have a reputation for their scientific, instrumental and technical achievements in both the optical-infrared and radio wavebands. Each has contributed in a major way to the remarkable history that has led to the current world-class status of the Australian

astronomy community. Facilities in these two broad areas will continue to be major contributors to our understanding of the Universe in their own right. The nature of astronomy is, however, evolving as astronomers become adept at utilizing tools in diverse disciplines to solve contemporary astrophysical problems. Of particular interest in the Australian context is that the coming generation of new radio facilities, ASKAP and SKA, as well as ALMA, which will provide opportunities for synergistic programs that return much more scientific insight and understanding than observations made from any one facility. Exciting discoveries are likely to be made as data are brought together from a range of facilities.

As discussed above, synergy between optical-infrared and radio facilities will play a key role in the future with the next generation of facilities like ASKAP and SKA. Since astronomy in Australia is built upon the two pinnacles of optical-infrared and radio observing, Australian astronomers can fully realize the potential of their new radio facilities with matching optical-infrared capabilities, provided they have significant access to 8-m and ELT-class optical-infrared facilities during the ASKAP and SKA era.

Operating Costs

The Committee emphasises the necessity of making adequate provision for the operating costs for the facilities proposed in the Decadal Plan for Astronomy. Recent experience in the USA and Europe indicates how important it is to develop appropriate plans for the long term operating phases of large astronomical facilities, and it has become routine recently to make “lifecycle” cost estimates from inception through operations. In the operational phase, the term ‘operating costs’ should not only include the ongoing operation of the facilities, but also the full infrastructure costs in maintaining an ongoing instrumentation programme, a facility maintenance programme, the costs of operating the time allocation panels, review committees and administrative infrastructure, and in some cases, an enhancement programme of the capabilities of the telescopes.

There is debate in the community about what fraction of the capital costs are needed per year to support the long-term viability of a national/international facility at the forefront of astronomical capability, but once all the above aspects of the operational phase are taken into account, the typical figure is about 10%. More specialized facilities or University-run facilities can operate more frugally, but even for such cut-price operations, the figure is unlikely to be less than about 5%. The current emphasis on lifecycle costs in the USA has brought this issue to the attention of the science community, and it has become routine at NASA, NSF and DOE to make a “bottom-up” assessment of the likely lifecycle costs as part of the evaluation and review process before approval of development funding.

The importance of this discussion is that the value of the capital facilities which can be satisfactorily operated depends upon the resources available per year to support operations. As an example, with a capital investment in facilities of $1B, operating costs of 10% indicate the need for operating funds at the level of 100 $M per year. While the exact details can be argued, the overall message is unavoidable – in long term investments such as large, general-purpose, ground-based telescopes, the operating costs on decadal

time scales are comparable to the capital costs and adequate provision needs to be made at the outset for covering these costs. It is essential that the planning for major new investments take full account of the necessary operating costs or the full scientific capability of the investments will not be realized.

Conclusions

The success of the Australian astronomy community in obtaining NCRIS funds attests to its role as one of the highest impact sciences in Australia. The "New Horizons" Decadal Plan advocates a development strategy for Australian Astronomy that is needed to keep its research competitive with the most advanced international programmes. Science, like most other endeavours, is increasingly global in nature and any truly successful national programme requires a combination of international collaboration and world leadership in selected areas. It is essential for Australian optical-infrared astronomy that it pursues both of these goals, collaboration and leadership, aggressively. The Decadal Plan provides a vision of how this can be achieved and the NCRIS funding goes a long way in allowing it to be realized.

Constrained resources necessitate prioritization and choices to be made. Therefore the ANSOC has studied the proposals submitted to it for the allocation of the Strategic Options funding and has assessed their importance in advancing optical-infrared astronomy in the coming decade. Our evaluations of the proposals submitted can be summarized as follows:

Continued Operation of the AAT

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 funds, the ANSOC considers the AAT to have great strategic value for the entire Australian community.

Additional Access to 8-m Class Telescopes

We fully support the view that substantial access to 8-m telescopes is crucial, and were very encouraged to hear of the ARC efforts to increase Australia's Gemini share by 4%. The committee considers that the complementary capabilities offered by the Magellan telescopes, and the success of the current Magellan access program, is the best match to Australian needs in the near-term, and we recommend the proposed purchase of the 15 nights per year until the end of 2011.

Investment in the GMT DDP

The next generation of large ground-based telescopes for the optical-infrared wavebands will be the source of important discoveries, and Australia must participate in the development of one of the existing consortia building ELTs. The ANSOC considers the GMT to be the best option for Australia in terms of its cost, partners, and planned instrumentation at the present time.

Uncertainties in final funding affect all international projects equally, but should not deter the development effort inasmuch as such telescopes will undoubtedly be built in the future. We consider that a 10% share in the partnership is a minimum level for Australia to be a significant, effective and influential player. To reach this figure, given the ANU's 5% commitment to the GMT, additional NCRIS funding on behalf of the national community at the level of 5% is needed. This is a very high priority and would ensure that Australia has a role comparable to other partners for the DDP.

The ANSOC considers the funding of the design and development phase (DDP) of the GMT to be of the highest priority, above that of operation of the project office and the risk mitigation activities.

Antarctic astronomy and PILOT

Participation of Australia in Antarctic astronomy is of great strategic value, and the efforts of Australian astronomers has enabled Australia to play a role in characterizing the opportunities and challenges for telescopes at areas such as Dome C. Antarctic astronomy is an ambitious undertaking and an appropriate long-term goal for Australia. We consider, however, the specifics of the submitted proposal are deficient in several regards. There is no firm commitment of participation by international partners in a 2.5 m telescope project, and there are serious questions about the budget estimates and aspects of project management. We believe the PILOT project would have to undergo a fundamental restructuring if it is to become credible. At this time, the Committee believes that intermediate scale research projects, coordinated with international groups, should be carried out to demonstrate the technical feasibility of all aspects of observing in Antarctica and that international collaborations, such as the current international PLATeau Observatory (PLATO) project on Dome A, should be enhanced.

Funding Recommendations

The ANSOC was charged with recommending allocations of available Astronomy NCRIS Strategic Options funds to the various proposals. The total funding request was for AU$12.035M and the available funds are AU$5.285M. Based upon our evaluation of the proposed projects, we believe the funding allocation shown in the Table is optimal for optical-infrared astronomy and should make a significant impact at the national and international level over the next three years. The funding needed by the programmes is subject to international exchange rate fluctuations and the figures will change from time to time.

Program	US$M	AU$M
Additional 8m Time: Magellan Telescopes	1.725	2.156
GMT Project: DDP 5%	2.330	2.913
TOTAL (Exchange rate of AU$1.0: US$0.8)	4.055	5.069

The residual funding should be retained initially to deal with possible currency exchange rate changes, and applied, if funds remain, to the support of the GMT project within Australia.

Appendix A - ANSOC Terms of Reference

- To assess the options for optical astronomy - additional 8-m time, GMT and PILOT - incorporated in the Astronomy NCRIS Investment Plan. For each option this assessment should specifically include:
  - The potential for novel scientific returns and for contribution to the resolution of the key scientific and technical challenges in 21st Century astronomy;
  - The potential to develop Australian astronomy and enhance its world position;
  - The feasibility and robustness of the proposed design and costing (for both construction and operation);
  - The risks associated with the option and the quality of the proposed mitigation strategies;
  - The feasibility that the international support necessary to deliver the option will be forthcoming on a timescale relevant to Australian decision making.
- To comment on any synergies between the options that might allow more than one to advance; and
- To similarly assess the scientific return from continued operation of the 4-m Anglo-Australian Telescope;
- In light of these assessments to recommend possible uses of the *available* Astronomy NCRIS Strategic Options funds to develop Australia's optical astronomy infrastructure and advance implementation of the Decadal Plan;
- To offer guidance on developing a future landmark proposal for implementing the Decadal Plan in optical astronomy.