REVIEW OF THE ANGLO-AUSTRALIAN OBSERVATORY

A Report of the AAO Review Panel

to the Minister for Education, Science and Training

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EXECUTIVE SUMMARY AND RECOMMENDATIONS

Executive Summary

Astronomy today is addressing some of the most fundamental questions underpinning our understanding of the nature and origin of the universe and of the emergence of life itself. Remarkable discoveries have been made in recent years that have not only enhanced our understanding of the universe but which have also thrown up more fundamental challenges. Australian astronomers have an outstanding track record in these developments and can boast of some of the most remarkable discoveries of recent years. The high reputation of Australian astronomy is an important component of Australia's global profile as a highly skilled and innovative nation. Our astronomy achievements are highly visible and are valued by the Australian public. The challenge and excitement of astronomy plays an important role in scientific education and in inspiring young people to take up careers in science and engineering.

The Anglo-Australian Observatory (AAO) and the associated Anglo-Australian Telescope (AAT), established as a major research facility in 1975 by the governments of Australia and the United Kingdom, has been central to optical astronomy research in Australia over this period. By an agreement signed in 2005 between the two governments, the current collaboration between the two countries will end on 30 June 2010, and the AAT and associated facilities will then transfer to Australian ownership and control. This Review was instigated in response to the withdrawal of the UK from AAT funding and governance arrangements. Its purpose was to evaluate the performance of the Anglo-Australian Observatory, make recommendations on how the AAO's performance might be enhanced, and advise on the future role of the AAO (and any successor organisation) in the context of the *Decadal Plan for Australian Astronomy 2005-2015*[1].

Performance of the AAO

The Panel found that the AAO has consistently been one of the world's most productive telescope service providers, producing first-class research outcomes for users of AAT data and for AAO staff. The AAO has been pivotal in helping Australian astronomers earn their current reputation as respected players in international astronomy. The AAO's instrumentation programme is world-leading and includes exceptional technological innovations. Current developments are creating significant international interest.

The AAO is operating in a highly cost-effective manner. The AAT Board has provided strong and appropriate oversight and strategic leadership. The Director, supported by his user advisory committees and senior management team, has provided highly effective management in providing world-class observing services to users of the AAO, both Australian and international. Cost efficiencies have been made where possible while maintaining world-class viewing services. The AAO is highly engaged in international developments in astronomy and, commensurate with its scale, is making very significant contributions.

Future Role and Budget for the AAO

The future role of the AAO must be determined in the context of international developments in astronomy and astronomical facilities. Telescopes and their instruments are increasing in size, sophistication and cost, and as a consequence require greater international cooperation. Significant opportunities for Australian optical and infrared astronomy lie in Australia's continuing involvement in the world's largest telescopes. Engagement with these international projects will ensure that Australian scientists, including those associated with the AAT, retain

[1] National Committee for Astronomy of the Australian Academy of Science, *New horizons: a decadal plan for Australian astronomy 2006-2015*, Canberra, 2005.

their prominent role and high reputation in one of the most visible and publicly-appreciated sciences.

Despite these trends the Panel found that the AAO could continue to provide world-class observing facilities until at least 2015 if a further instrumentation enhancement in the next three to four years was supported to maintain the telescope's scientific competitiveness. The AAO's facility and observing services, instrumentation science and development, and astronomical research are strongly synergistic and have been the key to the AAO's success. This combination of capabilities must be retained to ensure this continued contribution. The AAO would then be able to play a central role in supporting world-class research for another generation of Australian astronomers.

The Panel considered the AAO's future funding needs to fulfil this role and concluded that additional Australian funding amounting to a total of $10.5 million over the period 2006-07 to 2010-11 will be required. This amount will in part compensate for the reduction in the operating budget resulting from the withdrawal of the UK, a reduction in total of $14.8 million when compared with original funding levels. In addition funds of some $4.1 million will be required to undertake minimum refurbishment of the telescope infrastructure and a further $2.9 million for development of the new scientific instrumentation package. Operating budget support at the 2010-2011 level would be required to be included in the Forward Estimates out to 2015 and the Panel recommends a review of the situation be conducted at an appropriate time in 2010-11 to reaffirm the most appropriate way ahead.

The Panel concluded that the benefits to Australian astronomy and to the broader Australian community fully justified these additional investments. The AAO has an outstanding record of achievement of delivering world-class astronomical observing services and the Panel felt confident that this level of service could be maintained after the UK withdrawal with this additional budget.

The Panel found that there would be further potential benefits to Australia if the AAO performed a broader role in Australian astronomy as outlined in the *Decadal Plan for Australian Astronomy*. The AAO could provide an effective broader facility-management service to the Australian optical astronomy community, leading and coordinating a number of existing and new investment initiatives and providing a single point of advice to Government. For example, as a first step, the management of Australia's Gemini programme could be transferred from the Australian Gemini Office to the AAO. Proposals for interim and longer governance arrangements that also cover the withdrawal of the UK are also recommended.

Recommendations for the AAT Board and management are provided at page 19.

Recommendations to the Minister

1. The Panel recommends that the AAO should continue in its role as the major national facility manager for optical astronomy in Australia until at least 2015.

2. The Panel recommends that the Australian Government should increase the planned recurrent funding for the AAO by $10.5 million over the five-year period 2006-07 to 2010-11. This amount is $4.3 million less than the total baseline UK funding would have been over the same period.

3. The Panel, noting that the outstanding success of the AAO is based on the conjunction of research, instrumentation and facility management, recommends that maintaining this capability combination should be a priority when considering future funding for the AAO, in order to optimise delivery to the user community.

4. The Panel recommends that a new instrument be developed which will extend the life of the AAT for use by Australian researchers and students for at least the period to 2015 at an estimated cost of $2.9 million in the budget period 2006-07 to 2010-11. The Panel considers that the instrumentation capability of the AAO is central to its ability to deliver forefront astronomical capability to users, and in so doing ensures that the AAO retains a strongly competitive position worldwide as a builder of innovative instruments.

5. The Panel recommends that the AAO be refurbished as necessary, and that funds to address the two most critical categories of repairs (the Level 1 and 2 requirements) be sought to the amount of $4.1 million in the budget period 2006-07 to 2010-11.

6. The Panel recommends that the AAO be given the broader role of a national optical observatory, managing both national and international projects, and encompassing Gemini, ELTs, Antarctic astronomy facilities (see Glossary) and other national investments to the benefit of the Australian astronomical community.

7. The Panel recommends that an Optical Astronomy Australia Board (OAAB) should be established as a statutory corporation after 2010 to own and manage national facilities where appropriate, provide leadership and coordination of optical astronomy research in Australia, undertake strategic planning, provide a point of contact with the Australian Government and international organisations, seek and distribute major facility funds, and appoint the Director and manage the AAO.

8. The Panel recommends that an Interim OAA Board should be established in 2007 with broad responsibilities to lead and manage the optical astronomy programme in Australia from 2007-2010, with suitable transition arrangements as the UK's involvement in the current AAO reduces and ends in 2010.

9. The Panel recommends that consideration should be given in the future to widening the scope of the OAA Board to that of a broader peak body for all astronomy beyond 2010 and that the Minister should establish a working group in 2007 to consider the benefits and possible arrangements for this broader peak body.

10. The Panel recommends that the Minister should commission a further review in the period 2010-11 with the purpose of developing guidance for the AAO for the period out to 2015.

BACKGROUND

History of the Anglo-Australian Observatory (AAO)

In 1969 the governments of the United Kingdom and Australia signed the Anglo-Australian Telescope Agreement to build and operate the Anglo-Australian Telescope (AAT) at Siding Spring near Coonabarabran in New South Wales. The Siding Spring site chosen for the AAT is the site of an observatory, established in 1965, owned by the Australian National University. The two observatories share a number of facilities and instruments at Siding Spring.

Planning for the AAT commenced in 1967. It was decided that the AAT would be a 3.9-m telescope similar to the 4-m telescope of the Kitt Peak National Observatory in the United States. The telescope was commissioned in late 1974 and commenced scientific operations in 1975. In 1974 the AAO established a headquarters and laboratory in Epping, a suburb of Sydney, on a CSIRO campus shared with the CSIRO Division of Radiophysics (and later the Australia Telescope National Facility).

In 1988 another telescope located at Siding Spring, the 1.2-m UK Schmidt Telescope, operated by the Royal Observatory, Edinburgh, was brought under the control of the AAO.

Current governance and funding arrangements

Governance

The Anglo-Australian Telescope Board (AATB) is a statutory corporation, consisting of six members who are appointed (three each) by the Australian and United Kingdom governments. The three Australian positions on the AATB are currently filled by Professor Warrick Couch (of the University of New South Wales), Professor Brian Schmidt (of the Australian National University) and Mr Greg Harper (of the Australian Research Council).

The operations and budget of the AAO are managed by a Director (currently Professor Matthew Colless) who is appointed by the AATB. Two main advisory committees contribute to the operations of the AAO:

- the Anglo-Australian Observatory Users' Committee (AAOUC), which advises the Director on aspects of the Observatory's operation; and
- the Anglo-Australian Time Assignment Committee (AATAC), which allocates observing time.

The Director is assisted by a small administrative staff. Scientific and instrument programmes and telescope operations are supported by:

- 12 support astronomers and night assistants;
- 18 technical and engineering support staff; and
- 25 instrumentation development staff.

Funding

Until 2005-06 the AAO had annual revenues of around A$9.5 million. Around 80% of the AAO's revenue has been derived from financial contributions and grants from the two governments, with the remaining 20% mostly provided by AAO external instrumentation contracts.

In the period to 2010, the contribution from the UK is expected to fall to one-quarter of its previous level (see Table 1). Beyond 30 June 2010, the UK funding will fall to zero.

Recurrent Australian Government funding for the AATB has been secured through 2009-2010.

Table 1: Estimated Australian Government recurrent funding for the AAO for 2005-06 to 2009-10

	2005-06 $m	**2006-07 $m**	**2007-08 $m**	**2008-09 $m**	**2009-10 $m**
Australian recurrent funding Forward Estimates	4.594	4.701	4.795	4.891	4.988
Estimated UK contribution	3.412	1.850	0.925	0.925	0.925
Total	**8.006**	**6.551**	**5.720**	**5.816**	**5.913**

See Table 2 for the Panel's recommended level of recurrent funding.

NCRIS

$542 million has been made available through the National Collaborative Research Infrastructure Strategy (NCRIS) for the period 2006-07 to 2010-11 to provide researchers with access to major research facilities and the supporting infrastructure and networks necessary to undertake world-class research.

The *NCRIS Roadmap* announced in February 2006 identified optical and radio astronomy as one of the ten priority capability areas which Australia should aim to develop through significant infrastructure investment. Specifically, additional support for the AAO was nominated as one of three priorities for NCRIS investment in optical and radio astronomy, additional to the DEST recurrent funding.

A single national proposal for optical and radio astronomy is currently being developed by the astronomy community through a designated facilitator, with a funding proposal due to be submitted to DEST by September 2006.

Australian astronomy overview

Australia has a long and proud tradition of astronomy, both radio and optical spheres (note that throughout this report when the term 'optical' astronomy is used, it is intended to include 'optical and infrared' astronomy). Australians publish 3-4 % of the world's astronomical research output, and have an even higher share of the citations, which are widely recognised as a better metric for scientific productivity and success. The impact of Australian astronomical research has climbed markedly over the past decade, and it is now one of Australia's highest impact sciences. The quality of Australian research in astronomy has also been recognised in a number of major awards to Australian astronomers, which include fellowships of the Australian Academy of Science and of the Royal Society, Federation Fellowships, Pawsey Medals, the Shaw Prize for Astronomy, and the Malcolm McIntosh Prize for Physical Sciences. Australian astronomers are also prominent on international organisations such as the International Astronomical Union. The status of Australian astronomy in 2005 is reviewed in the *Decadal Plan for Astronomy 2006-2015*.

It is estimated that Australia invests about $60 million per annum in astronomy-related activities[2]. Of this, roughly two-thirds is used to fund university activities (including teaching). The total number of people involved in Australian astronomy has remained roughly constant over the past decade, although there has been a marked shift (mirroring trends in the broader society) from 'tenured' to fixed-term positions. Fifteen universities maintain astronomical research groups, and several departments operate institutional-level telescopes and observatories, which are also accessed by the wider Australian research community. Of particular importance here is the Siding Spring Observatory operated by the ANU. The Anglo-Australian Observatory and the Australia Telescope National Facility (CSIRO) are the two major national facilities, providing Australian astronomers with internationally-competitive facilities at optical and radio

[2] *Decadal plan*, vol II, WG1.1 report (Demographics).

wavelengths respectively. In addition, Australia is a member of the international Gemini Observatory, giving it a 6.19% share of the two 8-m Gemini telescopes.

Role of the Anglo-Australian Observatory as proposed in the *Decadal Plan*

The *Decadal Plan for Australian Astronomy 2006-2015* acknowledged that a major issue was the reduction of funding for the AAO by the UK. The *Decadal Plan* noted that by 2007 the AAT, and its parent organisation, the Anglo-Australian Observatory (AAO), will be 87% Australian-funded, while by 2010 it will be wholly Australian-owned.

The findings of the *Decadal Plan* were that:

1. The AAT will continue to be a world leader in survey astronomy for at least the next five years, and beyond that will be critical as the single biggest source of optical/infrared observing time for Australian astronomers.

2. During the decade, at least one more major instrument will be needed to maintain the telescope's scientific competitiveness.

3. By the end of the current decade the role of the AAT will have changed considerably, though the operational lifetime of the telescope will depend on the extent to which Australia achieves its goals of maintaining 8-m class telescope access and joining an ELT partnership.

Furthermore, the *Plan* noted that:

> The future of the AAO is a separable issue from that of the AAT. The observatory will have a clearly defined role while the AAT remains operational. Beyond that, it will continue to play an essential yet evolving role. The instrumentation program at the AAO is one of the very best in the world and it should be retained and developed as a national asset. Together with technology development in university instrumentation groups like the Research School of Astronomy & Astrophysics Advanced Instrumentation Technology Centre (RSAA AITC), it will be a key factor in allowing early engagement and influence in the next generation of telescopes[3].

[3] *Decadal plan*, p. 29.

THE AAO REVIEW

The Termination of the UK Agreement

Under the Anglo-Australian Telescope Agreement, either party had the right to terminate the Agreement with five years' notice. In 2001 the UK government advised Australia that it intended to end its involvement with the AAT in order to divert funding to other facilities, such as the European Southern Observatory and Gemini observatories, which operate next-generation 8-m optical telescopes.

Instead of the UK issuing a five-year termination notice, the two governments agreed to amend the original Agreement through a *Supplementary Agreement*[4], which was signed on 3 November 2005. This *Supplementary Agreement* provides for the current collaboration between the UK and Australia to end on 30 June 2010 at which time the AAT and associated facilities will transfer to Australian ownership and control.

New financing and access arrangements apply during the current transition period. Above a minimum level of $500,000 per annum, each country is able to determine the level of its contribution independently of the other, with observing time allocated in proportion to the contribution of each party. This arrangement allows a planned and gradual withdrawal of UK funding.

In response to the withdrawal of UK funding and the changed governance arrangements that will apply after 2010, on 15 November 2005, the former Minister for Education, Science and Training, the Hon Dr Brendan Nelson MP, commissioned this Review to evaluate the performance of the Anglo-Australian Observatory (AAO) and to advise the Government on future organisational and funding options (see Terms of Reference at Appendix 1).

The Review process

In January 2006 Dr Ian Chessell (chair), Professor Garth Illingworth and Professor John Storey agreed to serve as members of the Review Panel (see Appendix 2).

On 9 February, an issues paper and call for submissions (by 24 March) were announced on the AAO Review website[5]. A total of 25 submissions were received (see Appendix 3).

DEST engaged consultants ACIL Tasman to produce an economic impact assessment of the AAO (see summary of report at Appendix 4).

The Review Panel, supported by a DEST Secretariat member, convened at the AAO laboratory at Epping on 10-13 April for a series of consultations, including a one-day site visit on 11 April to the AAT site at Siding Spring (see Appendix 5).

The Anglo-Australian Observatory's submission to the Review

In its 118-page submission, the AAO provided detailed information on its facilities and services, scientific outcomes, instrumentation programme, education and outreach activities, management and governance, plans for the period to 2010, and funding and governance issues after 2010. The Panel found this document to be an extremely well written and comprehensive resource, and appreciated the effort made by the AAO.

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[4] A *Supplementary Agreement between the Government of the Commonwealth of Australia and the Government of the United Kingdom of Great Britain and Northern Ireland concerning the Anglo-Australian Optical Telescope, at Siding Spring, New South Wales, Australia.*

[5] <http://www.dest.gov.au/sectors/science_innovation/policy_issues_reviews/reviews/anglo_aus.htm

The submission outlines a strategic plan for managing the UK's withdrawal from the AAO and the transition to a wholly Australian facility. The AAO estimated that for this purpose it would require a total of $33.1 million from 2006 to 2010, comprising $24.3 million in recurrent funding from the Australian Government and $8.8 million capital investment from the NCRIS process. The AAO's 'base scenario' budget at Appendix 6 detailed its projected income and expenditure, extended to 2010-11.

Assessing various organisational models for the AAO against desirable governance and funding principles, the AAO favours a 'new AAO' model wherein the current AAO would be reinvented as the 'Australian Astronomical Observatory'. The new AAO would retain the AAO's current strengths and expand its functions into a national observatory (i.e. a peak body) for optical and infrared astronomy. The new AAO would be owned and governed by an independent Board, a legal entity broadly similar to the present AAT Board, appointed by the Minister and including representatives of the user community and other stakeholders.

The AAO also sees advantages in a more radical 'hybrid' model in which an independent Board would own and manage both optical/infrared facilities and the radio astronomy facilities currently owned and managed by CSIRO as part of the Australia Telescope National Facility (ATNF). The resultant organisation would form a peak body for all Australian astronomy. The AAO considers that the hybrid model raises some challenging issues, and thus proposes that the new AAO be formed and 'bedded in' before any steps are taken to form it into a national astronomy peak body.

Other submissions

A total of 25 submissions to the AAO Review were received. The Panel greatly appreciated the thoughtful responses from the astronomical community and a wide range of other interested parties. Common themes, particularly in submissions from AAO committees, the AATB, and university astronomy departments (the majority of submitters), were:

- the AAO is a leading research facility with leading-edge instrumentation;
- the existing governance arrangements (i.e. the AATB) are successful;
- a peak body for optical/IR (optical/infrared) astronomy is needed and the oversight body for the AAO would be suitable;
- the AAO needs a new instrument to maintain this leadership position beyond 2010;
- an increase in, or stable, recurrent Australian Government funding is needed; and
- university users would benefit from improved support (particularly for travel) and access to the AAT.

Submissions from organisations associated with the Coonabarabran region made the following points:

- the AAO provides employment, educational, commercial and community benefits to the region;
- the AAO staff play a strong role in the vitality of the local community; and
- the local community is committed to protecting good environmental conditions for astronomy.

The Particle Physics and Astronomy Research Council noted that the UK values the facility and will continue to do so.

A list of submissions is at Appendix 3.

PERFORMANCE OF THE ANGLO-AUSTRALIAN OBSERVATORY

Scientific outcomes

- World leading research outcomes from both AAO staff and users of AAO data.
- The survey of the large-scale structure of the universe (2dF, or two-degree field fibre spectrograph) is a landmark achievement.
- The AAO has been pivotal in allowing Australian astronomers to earn their current reputation as competitive players in the international astronomy community and has contributed to astronomy becoming a science icon in the Australian community.

The AAT has consistently been one of the world's most productive telescopes. The most recent quantitative analysis compares publications from the world's 250 largest optical telescopes in the year 2001[6]. The AAT is an outstanding performer, with the third highest total number of citations and the third highest number of citations per paper of *any* optical telescope in the world, regardless of size. Of the 16 most highly cited papers for that year, three are from the AAT. Since 2001 the number of papers per year based on AAT data has actually risen slightly, demonstrating that the facility remains highly competitive. This is a remarkable achievement for a 4-m telescope and demonstrates the excellence of its instrumentation programme and the skill and scientific insight and resourcefulness of its scientific staff and the research community.

Scientific highlights include the 2dF Galaxy Redshift Survey, which mapped the large-scale structure of the universe as traced by 221,000 individual galaxies, and the discovery of 20 new planets around other stars by the Anglo-Australian Planet Search.

The AAT has been pivotal in helping Australian astronomers to earn their current reputation as respected players in international astronomy. Typically, around 30 Australian-based Principal Investigators (PIs) use the telescope each year. Observing programmes on the AAT also make a major contribution to the training of research students based in Australian universities. Nineteen students used AAT data in their theses during the period 2001-05. The AAO has also made important contributions to undergraduate education; for example, through the Summer Student programme which has been exceptionally successful in generating a flow-on of talented students into postgraduate programmes across a range of scientific fields (not only astronomy). 57 of the 60 AAO summer students over the past decade have gone on to PhD study. Astronomer-trained graduates find employment in a wide diversity of fields ranging from computer science to defence, being highly valued for their training and experience in innovation and research methodology.

The UK Schmidt Telescope (UKST) also continues to be highly productive by world standards; its 40 publications in 2001 placed it at the top of the list of comparable telescopes. However, at the present time there are several new, much larger survey telescopes under development around the world, and the UKST will not remain competitive as a general-purpose facility. It does currently have value as a facility that is used by groups on an operational cost-recovery basis and so brings scientific returns to the community.

Facilities and services

- The AAO has been outstandingly cost effective, despite the fact that it is no longer amongst the largest telescopes in the world at the present time, and has had a scientific impact that places it among the most productive telescopes in the world.

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[6] V Trimble, P Zaich and T Bosler, 'Productivity and impact of optical telescopes', *Publications of the Astronomical Society of the Pacific*, vol 117, 2005.

Comparison of the operating cost of the AAO with that of similar-sized optical/IR telescopes internationally shows the AAO to be operating as efficiently as other general-purpose facilities. However, given the very high level of scientific productivity relative to these facilities, it is clear that the AAO is operating in a highly cost-effective manner as a research tool. The reduction in the operating budget of the AAO that would result from the ramp-down of UK funding will, if not supplemented by an additional Australian contribution, place it well below the level deemed appropriate by operators of comparable international facilities.

After decades of highly cost-effective operation, the UKST is no longer competitive as a general-purpose facility, as noted above. Operational costs have therefore been devolved to the users on an operational cost-recovery basis. Nevertheless, staged refurbishment of the UKST to keep it operational remains a significant budget item for the AAO (these costs have not been part of the cost-recovery to date), and these costs must be weighed against other priorities or included as part of the cost-recovery approach.

Instrumentation programme

- The instrumentation programme is world-leading and includes exceptional technological innovations such as multi-object fibre spectroscopy.
- This programme promises continued leadership with innovations such as OH suppression fibres and Starbugs.

The AAO instrumentation programme has been, and continues to be, world class. Technical innovations, such as multi-object fibre spectroscopy, have been a major factor in maintaining the competitiveness of the AAT for over three decades. Such innovations also make a significant contribution to the international visibility and reputation of Australian astronomy, and create opportunities for winning substantial instrumentation contracts from overseas.

Maintaining a core instrumentation team of outstanding scientists and engineers will allow the AAO to maintain its record of innovation into the next decade. Current ideas, such as OH-suppressing optical fibres and micro-positioner technology (Starbugs) are creating significant international interest.

Management

- Positive responses from user surveys support the highly effective management by the AAO Director and the excellent management oversight and guidance that the AAT Board has provided to users of the AAO.

The management structure of the AAO has been extremely effective in creating a truly national facility that is both responsive to the needs of the astronomical community and provides equal access to all Australian astronomers. The AATB itself has provided appropriate oversight and bold strategic leadership, thus ensuring that the AAO can function effectively and without undue external interference. By establishing the AAO from the outset as an organisation that supports, rather than competes with, university-based researchers, the AATB has provided a good model of how the future management of the AAO might be structured. The Panel considered the leadership and management provided to the Observatory by the Director and his senior staff was outstanding. Their vision, energy and focus on the service delivery to their clients were clearly evident to the Panel. The Director's advisory committees, the AAOUC and the AATAC, are well respected by the community and provide an excellent feedback mechanism for client needs and priorities to the AAO. Submissions from the astronomical community to this Review provide a broad-based and very strong endorsement of the way in which the AAO has been managed, and stress the importance of maintaining its independence.

FUTURE OF THE ANGLO-AUSTRALIAN OBSERVATORY

International and technical contexts

International Framework

The future of astronomical facilities is being defined by the increasing size and sophistication of the telescopes and the instrumentation needed to address the major scientific questions that confront us. The nature of the dark energy that is driving an accelerated expansion of the universe, the form of the dark matter that permeates the universe and dominates the mass of galaxies, and the ways in which galaxies grow from seeds at the earliest times, some 13.5 billion years ago, through to present day objects like our Milky Way, are questions that provide a framework on the largest scale. Much closer to us are questions about how stars like our Sun form, how the planetary systems that are now known to be quite ubiquitous grow as part of the birth of stars, and ultimately to the existence of other planets like our own.

Answering questions like these presents great technological challenges. Astronomers expect to be able to move ahead on these by developing and using technologies in novel ways, by taking innovative and imaginative approaches using existing facilities with new instruments and by building some larger facilities. New technologies in the optical/IR area involve very large light detectors for taking very large images, sophisticated optical systems, novel ways of moving light through optical and infrared fibres and ways of making the images on the ground approach those in space in their quality and resolution (through adaptive optics). These technologies can be combined to make new instruments that give new life to older facilities, while also making it practical to envisage building telescopes in the 20-30-m range in size (very much larger than the 4-6-8-10-m facilities in use today).

A key aspect that will make such facilities practical is increasing international cooperation as the facilities are large and expensive. They also need to be located in places where the sky is clear and the atmosphere stable enough to produce superb images. Places such as Chile and the tops of 2,000-4,000-m mountains on islands or near the west coasts of major continents are being exploited now and will be for the next generation of such facilities.

A major radio facility, the Atacama Large Millimeter Array (ALMA), which is being built in Chile on a 5,000-m high site by Europe, the USA and Japan, in cooperation with Chile, for a total cost of around US$1 billion, provides a strong incentive for powerful optical/IR facilities in the southern hemisphere at comparable latitudes. The scale of this project, the largest ever astronomical project on the ground, is generally recognised to be around the upper limit that is practical, even given multiple international partners. Others, like the Square Kilometre Array radio telescope (SKA) and a 30-m optical/IR telescope, will likely approach this level in cost, and are expected to be major international programmes.

However, many other facilities are under consideration that would cost much less. Of particular interest are instrumentation projects like new cameras and spectroscopic systems that cost millions of dollars to tens of millions of dollars. These leverage very effectively the investment in telescopes in the 4-10-m range. Again many of these projects are international to both enhance the technology base and to spread the cost burden around amongst a number of funding agencies.

Opportunities for Australia

Australia's strengths in the optical and infrared arena lie with its very scientifically-productive and internationally-renowned community of astronomers, complemented by a strong programme of technological leadership in instrumentation in several areas. These include the use of optical and near-infrared fibres to bring the light together into a compact instrument from

the many galaxies and stars that are spread over large areas of the sky, wide-field optical systems to make such fibre instruments practical, efficient electro-mechanical systems for moving the fibres around (Starbugs), and well-engineered optical and near-infrared camera systems to convert the light into electronic signals. A particularly powerful technology is also under development at the AAO to utilise fibres to reject much of the light from the sky and enable ground telescopes to approach space telescopes in sensitivity (OH-suppressing fibres).

Continuing such developments and support for their implementation in facilities, both within Australia but also increasingly in the coming decade on the world's largest telescopes outside Australia, will keep Australian scientists at the forefront scientifically and technologically, and fully competitive with their Chinese, European, Japanese and USA peers. Continuing (and enhanced) involvement with the Gemini 8-m telescopes will ensure Australian scientists have access to contemporary facilities that are at the forefront. Direct involvement at a level consistent with Australian funding in the next generation of 20-30-m class telescopes will ensure that Australia and Australian scientists retain their very strong role in what is one of the most visible and publicly-appreciated sciences.

The Panel concluded in the context of these international trends, Australia's current strengths and the outstanding record of achievement of the AAO, that the AAO could continue to play a highly effective role in supporting research in optical astronomy in Australia at least to 2015.

Recommendation 1: The Panel recommends that the AAO should continue in its role as the major national facility manager for optical astronomy in Australia until at least 2015.

Budget

To carry out this role the AAO will require additional funds as the current budget position of the AAO is heavily impacted by the planned withdrawal of UK funding over the period 2006-07 to 2009-10. Table 2 in Appendix 6 sets out the AAO's original preferred future budget (its base scenario) and illustrates this impact. In the five-year period 2006-07 to 2010-11 the reduced UK funding amounts to $3.7 million in total, a reduction of $14.8 million in total when compared to the level of UK funding in 2005-06. At the request of the Panel, the AAO subsequently created an alternative budget scenario (Table 3 in Appendix 6) which relies less on anticipated income from the WFMOS contract.

The AAO submission proposes three steps to overcome these reductions:

- to seek additional recurrent funding from the Australian Government of $7.4 million over this period;
- to increase substantially external instrumentation earnings through winning significant work on the next phases of Gemini Telescope's WFMOS (Wide-Field Multi Object Spectrograph) instrumentation contract; and
- by moving approximately half of the current instrumentation team staff (Instrumentation Science and Instrumentation Groups) to contract positions, engaging them as and when work is won.

The ACIL-Tasman Economic Impact Assessment concluded that (unspecified) savings could be made by the AAO by reducing emphasis and therefore expenditure on telescope down-time and level of support services, matters which are key functions of an observatory. The Panel considered that the AAO was already operating as a 'lean and mean' facility, with a very focused and efficient multi-tasking workforce, and that this strategy, if carried very far, would lead to a rapid fall-off in the AAT's ability to support world-class research in Australia in the next decade.

In considering the AAO strategy for meeting the new budget situation, the Panel enquired into the level of risk associated with the WFMOS contract, which was found to be high, both in terms of potential contract delays or scope changes, and in terms of the competitive position of Australia, particularly given that Australia is a small contributor to the Gemini programme. The risk to the core AAO capabilities was considered to be high if this budget strategy was adopted. A recent delay in the ramp-up of funding, announced since the AAO Review in April, for the next generation of Gemini instruments because of budget pressures on the Gemini Observatory, gave added weight to this concern. The likelihood of the AAO not being able to deliver scientific outcomes for Australia in the next decade would thus be high.

In view of these conclusions, the value that the Panel places on the role of the AAO in contributing to the excellence of Australian science, and having reviewed a number of options for funding, the Panel concluded that the AAO's proposal as provided in its submission (Table 3, Appendix 6), while demonstrating commendable entrepreneurship, represents too high a level of risk, and recommends adoption of a modified version that maximises and maintains a set of options which ensures Australia's ability to remain at the forefront of optical/IR astronomy.

The revised budget proposed by the Panel is set out in Table 4:

Table 4: Review Panel's proposed increase in Australian Government recurrent funding 2006-07 to 2010-2011

Year	Original $m	2006-07 $m	2007-08 $m	2008-09 $m	2009-10 $m	2010-11 $m	Total $m
UK contribution	3.7	1.9	0.6	0.6	0.6	0.0	3.7
UK contribution lost		1.8	3.1	3.1	3.1	3.7	14.8
Increase in Australian Government recurrent funding proposed		0.2	1.8	2.1	2.8	3.6	10.5

The additional recurrent funding recommended is still less than the UK funding that would have been received over the same period by $4.3 million. The Panel considered that it was realistic for the AAO to address this shortfall through increased external earnings and internal cost savings.

Recommendation 2: The Panel recommends that the Australian Government should increase the planned recurrent funding for the AAO by $10.5 million over the five-year period 2006-07 to 2010-1. This amount is $4.3 million less than the total the baseline UK funding would have been over the same period.

Noting the benefits to Australia of the AAO's collaboration with the UK, the Panel recommends that the Board explores opportunities to develop substantial partnerships with third parties (see Recommendation 7 to the AAT Board). New collaborations would broaden the AAO's support base and allow it greater flexibility to address opportunities such as ELTs and Antarctic astronomy. For example, a relationship with Japan would build on the instrumentation linkages already in place and those which could be developed further through the WFMOS and Echidna[7] programmes However, the Panel considers that the Australian Government should not necessarily rely on partnerships with other countries as a source of funding – the likelihood of success is just not known at this time.

[7] FMOS/Echidna is a fibre positioner being built by AAO for a near-infrared spectrograph on the Japanese Subaru 8-m telescope.

Internal capabilities

As noted, the AAO has established three world-class capabilities in delivering its viewing services: facility management and observing services, instrumentation science and development, and astronomical research. These capabilities are strongly synergistic and are tightly integrated in the organisation and in its service delivery processes. Top research astronomers all provide viewing assistance to visiting astronomers and input to concepts and needs for innovative instrumentation; instrumentation development adds to the AAT's capability to keep it at the leading edge, which in turn facilitates world-class research to be conducted at the AAO. All three capabilities contribute to Australia's international reputation for excellence in astronomy by directly supporting the user community.

In view of the funding pressures facing the AAO as a result of the UK withdrawal, the Panel considered various options for reducing the AAO's scientific and technical capabilities and concluded that the value of synergies attached to the three capabilities were such that any significant reduction in any of the three would seriously impair the quality of service delivery provided by the AAO and impact significantly on research quality.

Recommendation 3: The Panel, noting that the outstanding success of the AAO is based on the conjunction of research, instrumentation, and facility management, recommends that maintaining this capability combination should be a priority when considering future funding for the AAO, in order to optimise delivery to the user community.

The Panel encourages the AAO management to maximise opportunities to transition its technologies to Australian industry by showcasing its capabilities at, for example, International Society for Optical Engineering (SPIE) meetings, Australian industry forums and networks, the Australian Innovation Forum and the Australian Defence Industry Network, and to be proactive in identifying other potential opportunities for interaction with industry and with technology-focused university programmes.

The international competitiveness of astronomical telescopes depends heavily on a continuous programme of instrument upgrades to maintain the capability of the telescope to support leading-edge observations. The AAO programme of instrumentation development has allowed Australian optical astronomy to maintain its position with the best in the world despite the telescope itself now being some 35 years old. The strong view was put to the Panel that current instrumentation packages have a life of some two to three years at this leading edge and that there is perhaps a final opportunity to maintain the AAT's competitiveness to about 2015 if a further instrumentation capability is developed. Several options for this new capability are currently being explored. The Panel took the view that a further investment in new instrumentation was warranted, for the following reasons:

- the AAO has a proven record to deliver such upgrades;
- a new instrument would be highly leveraged from the current strong technology base at the AAO and so would be a very cost-effective enhancement;
- such development would maintain the development team and position it to compete for international instrumentation projects; and
- such a development would contribute to the development of another generation of world-class Australian astronomers.

Recommendation 4: The Panel recommends that a new instrument is developed which will extend the life of the AAT for use by Australian researchers and students for at least the period to 2015 at an estimated cost of $2.9 million in the budget period 2006-07 to 2010-11. The

Panel considers that the instrumentation capability of the AAO is central to its ability to deliver forefront astronomical capability to users, and in so doing ensures that the AAO retains a strongly competitive position worldwide as a builder of innovative instruments.

The Panel was advised that the AAO would seek these funds through the current NCRIS funding process and the Panel supports this application.

Infrastructure Refurbishment

The AAO has recently identified a number of significant infrastructure problems, some of which require urgent attention. Matters affecting occupational health and safety are currently being attended to. An expert consultant has been engaged and has developed a prioritised set of requirements in a report to the AAO. The Panel did not consider these in detail but endorses the proposed approach to seek funding for the two most critical categories of repairs (Level 1 and Level 2), in line with the Panel's view that the AAO can continue supporting world-class astronomy until at least 2015. Other requirements such as support for the UKST should be addressed on a needs basis as they arise. The ability of users to contribute to the refurbishment and opportunities to trade off time and money against operational reliability should be explored.

Recommendation 5: The Panel recommends that the AAO be refurbished as necessary, and that funds to address the two most critical categories of repairs (the Level 1 and 2 requirements) are provided in the amount of $4.1 million in the budget period 2006-07 to 2010-11.

The Panel was advised that the AAO would seek these funds through the current NCRIS funding process and the Panel supports this application.

Governance

The Panel considered current governance arrangements (outlined above) to be a major contributor to the success of the AAO over past decades. Particular governance aspects are the institutional independence of the AAO, the sound leadership and scientific direction provided by the Board (AATB) and the Director, and the strong paths for user input established through the AAO Users' Committee (AAOUC) and the Anglo-Australian Time Assignment Committee (AATAC) that prioritises telescope time allocation. These arrangements would be expected to continue until UK participation ceases in 2010. As Australia deepens its participation in a range of international optical research programmes in the next few years, the Panel considers that the AAO could provide a very effective broader facility-management service to the Australian optical astronomy community, managing both national and international facilities to which Australia has access. The AAO has the expertise, international standing and connections, and the demonstrated facility management experience, to undertake this role. A first step would be to transfer management of Australia's Gemini programme to the AAO, transferring the role and budget of the current Australian Gemini Office (AusGO). This role was proposed in the *Decadal Plan*.

Recommendation 6: The Panel recommends that the AAO be given the broader role of a national optical observatory, managing both national and international projects, and encompassing Gemini, ELTs, Antarctic astronomy facilities and other national investments to the benefit of the Australian astronomical community.

The Panel recognised that in the next few years Australian astronomical research programmes will become more international in scope, and more complex in terms of negotiating observation time and work share on large instrument development projects. Participation will be potentially more expensive and opportunities will therefore require careful planning and detailed expert analysis to ensure Australia maintains its leading position despite its comparatively small size. The Panel considers a 'Peak Optical Astronomy Body' should be formed to be responsible for

ensuring appropriate Australian representation in international forums, to coordinate national initiatives for participation in projects such as Gemini, ELTs and Antarctic astronomy, to undertake a wider role, and to provide advice to the Minister on funding needs and prioritisation. The need for such a body has been canvassed in the *Decadal Plan*. We have called this body the Optical Astronomy Australia Board (OAAB) here for clarity. The OAAB would replace the current AAT Board at the conclusion of UK involvement in the AAO. Board membership should be responsive to community and Government needs. The OAA Board would also subsume the functions of the Australian Gemini Office. (Indicative budget for that Office would be $75,000 per annum.)

Recommendation 7: The Panel recommends that an Optical Astronomy Australia Board (OAAB) should be established as a statutory corporation after 2010 to own and manage national facilities where appropriate, provide leadership and coordination of optical astronomy research in Australia, undertake strategic planning, provide a point of contact with the Australian Government and international organisations, seek and distribute major facility funds, and appoint the Director and manage the AAO.

Decisions on Australian involvement in a number of major international facility developments will be required in the next three to five years, and the Australian Government will require expert advice on priorities and trade-offs if Australia is to optimise its research opportunities for many years ahead. The Panel therefore considers there would be considerable advantage in forming an Interim OAA Board before 2010 to oversight these initiatives and provide advice to Government. This Interim Board would work closely with the AAT Board, include Australian AAT Board members and other suitable representatives of the community, and would subsume the functions of the AAT Board beyond 2010. It would be the recipient of DEST and other funding and allocate these funds to the community. It would subcontract work items such as facility management and international representation to the AATB as appropriate. Establishing such a Board earlier than 2010 would minimise the likelihood of problems during the transition from joint ownership to Australian ownership. These arrangements are illustrated in Figure 1 (Appendix 7).

Recommendation 8: The Panel recommends that an Interim OAA Board should be established in 2007 with broad responsibilities to lead and manage the optical astronomy programme in Australia from 2007-2010, with suitable transition arrangements as the UK's involvement in the current AAO reduces and ends in 2010.

The Panel gave considerable attention to the possibility of enlarging the roles of the proposed OAA Board to cover both optical and radio astronomy, i.e. to oversight and manage all national astronomical research and facilities in Australia and internationally. There would be considerable benefit to the Australian Government, as broad advice on priorities and trade-offs for the whole of astronomy could be provided. Synergies between opportunities in both optical and radio astronomy could be exploited. A coherent planning process could be instigated and a single point of contact established for astronomy in Australia. A variety of views on the concept were provided to the Panel during the Review and the Panel concluded on balance that taking such a step now without broad discussion could be potentially counter-productive given institutional positions. Rather the Panel proposes that it should be considered by the Minister for initiation at a later time. The establishment of a working group in 2007 with a charge to provide advice on the role and nature of this broad peak body would provide a means to assess to the pros and cons of such an oversight group.

Recommendation 9: The Panel recommends that consideration should be given in the future to widening the scope of the OAA Board to that of a broader peak body for all astronomy beyond 2010 and that the Minister should establish a working group in 2007 to consider the benefits and possible arrangements for this broader peak body.

Future Review

The situation of optical astronomy in a global sense is changing rapidly with technology enhancements and new international cooperative initiatives. In the following three to five years many decisions on major long-term developments will be made which will have the potential to make significant impacts on Australia's position. In this period the potential for winning external contracts will have been tested by the AAO instrumentation team and its impact on the AAO budget and capabilities better able to be estimated.

Recommendation 10: The Panel recommends that the Minister should commission a further review in the period 2010-11 with the purpose of developing guidance for the AAO for the period out to 2015.

Recommendations for the AAT Board

During the Review a number of issues were highlighted to the Panel which are relevant for the AAT Board and management to consider and these are gathered here.

1. The Panel views the AAO's educational and training role as vital and recommends the establishment of new incentives such as top-up scholarships, and a broadening of programmes to include more technical and engineering students. Indicative costs: $30,000 p.a.

2. The Panel recommends that consideration be given by the AAO to providing travel support to Australian graduate students, postdoctoral researchers and observers using the AAT. Indicative costs: $120,000 p.a.

3. The Panel sees considerable value in the outreach programme and recommends that the AAO seeks additional funding sources to support a more substantial programme. Indicative costs: $70,000 p.a.

4. The Panel recommends that the AAO give greater emphasis to opportunities for transition of its technologies to Australian industry. Indicative costs: $70,000 p.a.

5. The Panel recommends that where facilities are being considered for targeted scientific projects on a cost recovery basis (such as the current project utilising the UKST), the AAO makes an announcement of opportunity and seeks competitive proposals by a specific deadline.

6. The Panel recommends that the Board explores opportunities for provision of observing services or developing more substantial partnerships with third parties, particularly in the Asia-Pacific region, building on existing relationships.

APPENDICES

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Appendix 1

Terms of reference

The Review's terms of reference were to:

- Evaluate the performance of the AAO over the last five years in relation to:
    - scientific outcomes;
    - quality of facilities and services provided to users;
    - the internal and external instrumentation programme (including technological innovation in the programme); and
    - the overall management of the Observatory by the Anglo-Australian Telescope Board (AATB).

- Make recommendations on how the performance of the AAO might be enhanced; including identifying those areas of scientific strength which should be maintained and developed by the AAO, and any weaknesses and gaps that the AAO should address.

- Advise on the future role of the AAO (and any successor organisation), in the context of the *Decadal Plan for Australian Astronomy 2005-2016* prepared by the National Committee on Astronomy, addressing (but not necessarily limited to) the following specific issues:
    - opportunities and threats over the next five years that might impact on the ability of the AAO to achieve its mission and objectives;
    - the organisational, governance and funding arrangements that might apply when the AAT and associated facilities are transferred to Australian ownership and control in July 2010;
    - actions that might be taken by the AATB leading up to July 2010 in preparation for the new arrangements; and
    - the funding position and requirements of the AAO while the *Anglo-Australian Telescope Agreement* remains in place.

Appendix 2

Review Panel members

Dr Ian Chessell (Chair)

Dr Chessell retired as Australia's Chief Defence Scientist in 2003 following a career in the Defence Science and Technology Organisation. Dr Chessell served as a member of the Prime Minister's Science, Engineering and Innovation Council (2001-2003) and in 2003 he was awarded the Centenary Medal for services to defence science. Dr Chessell was elected a Fellow of the Australian Academy of Technological Sciences and Engineering in 2003. Dr Chessell is presently undertaking independent research and consulting projects. He is an Adjunct Professor in Systems Engineering with the University of South Australia and is the Chair of the independent Technology Advisory Council of Tenix Pty Ltd, Australia's major shipbuilding company. He is a member of the SA Defence Industry Advisory Board.

Professor Garth Illingworth

Professor Garth Illingworth is Professor of Astronomy and Astrophysics, University of California Observatories/Lick Observatory. His primary research interests are understanding when and how galaxies formed. He chairs the Astronomy and Astrophysics Advisory Committee (AAAC) that advises Congress and NSF, NASA and DOE on the implementation of the science programme developed by the astronomy science community through studies carried out by the National Academy of Sciences.

Professor John Storey

Professor Storey is Professor of Physics at the University of New South Wales and an astronomer with special research interests in Antarctic astronomy, infrared and millimetre astronomy, and energy efficient vehicles. He was awarded the Robert Ellery Lectureship by the Astronomical Society of Australia in 1999 for outstanding contributions in astronomy.

Appendix 3

List of submissions

(In order of receipt.)

No.	Organisation	Contact name
1	Anglo-Australian Telescope Board (AATB)	Dr Patrick Roche
2	Australian National University (ANU) (The ANU subsequently provided the Review with an addendum to its submission)	Professor Penny D Sackett
3	Australian Geographic	Ken Eastwood
4	Member for Upper Hunter Legislative Assembly Parliament of New South Wales	George Souris
5	Rural Development Western NSW NSW Department of Planning	Peter Downes
6	[Independent]	Dr Kevin Pimbblet
7	Particle Physics and Astronomy Research Council (PPARC)	Professor Richard Wade
8	Swinburne University of Technology	Professor Duncan A Forbes
9	University of New South Wales (UNSW)	Dr Michael Burton
10	University of Queensland (UQ)	Dr Michael Drinkwater
11	University of Southern Queensland (USQ)	Dr Brad Carter
12	University of Sydney	Dr Andrew Hopkins
13	Anglo-Australian Observatory Users Committee (AAOUC)	Dr Andrew Hopkins
14	Warrumbungle Shire Council	Rebecca Ryan
15	University of Melbourne	Professor Rachel Webster
16	Anglo-Australian Observatory (AAO)	Professor Matthew Colless
17	Sinclair Knight Merz	Jeff Ruckman
18	Anglo-Australian Time Assignment Committee (AATAC)	Dr Martin Asplund
19	Queensland University of Technology (QUT)	Dr Stephen Hughes
20	Coonabarabran and District Chamber of Commerce Inc.	Donna Burton
21	Astronomy and Astrophysics Graduate Students of Australia (AAGSA)	Stephen Fine
22	Council of the Astronomical Society of Australia	Professor Gary Da Costa
23	[Independent]	Professor John Lattanzio
24	CSIRO Australia Telescope National Facility	Professor Brian Boyle
25	Australian Research Council	Greg Harper

Appendix 4

Anglo-Australian Observatory – Economic Impact Assessment

Prepared for DEST by ACIL Tasman

Summary

The key points of the four-page "Executive Summary and Conclusions" of the ACIL Tasman report are:

- There are modest prospects for commercial and human resource spin-offs from the AAO.
- The rationale for public investment in the AAO and optical/IR astronomy more broadly must rest mainly with the value of the science outputs.
- ACIL Tasman accepts that the AAO has a strong scientific record.
- While the useful scientific life of the 4-m AAT is approaching its limit, it is expected to offer leading-edge capability until around 2012 (through the new AAO-developed instrument AAOmega).
- Another new instrument (the AAOmicron planned by the AAO) could allow the AAT to deliver leading-edge astronomy well beyond 2012.
- ACIL Tasman considers that most of the main goals of the AAO's bid could be achieved at lesser cost than the AAO bid. The saving is not quantified but is seen as arising from the AAO relaxing strong emphasis on support services for observing astronomers and avoiding telescope 'down time' (ie key functions of an observatory), while maintaining the emphasis on instrumentation (which is seen as helping maximise Australia's value from its investment in 8-m telescopes, and later, ELTs).
- Overall, and in a qualified way, ACIL Tasman sees merit in a funding scenario which lies somewhere above maintaining Australia's funding at current levels out to 2015 but below the AAO's bid.

Appendix 5

Interviewees and meeting schedule

Date	Time	Event	Interviewee/s
10 Apr	0845	Welcome and introduction	
	0900	Overview of AAO	Matthew Colless
	1000	Future of AAO	Matthew Colless
	1130	Instrumentation	Sam Barden
	1230	Lunch with Epping staff	
	1330	Instrument science	Joss Bland-Hawthorn
	1430	Astronomy	Chris Tinney
	1530	Afternoon tea with Admin/IT staff	
	1600	Discussion	Admin/IT staff
	1630	Decadal Plan for Astronomy	Brian Boyle
	1700	Discussion with Director, Australia National Telescope Facility	Brian Boyle
	1730	Panel discussion	
	1800	Discussion with AATB Chair	Pat Roche
11 Apr	0930	Tour of AAT at Siding Spring and AAOmega inauguration	Chris McCowage
	1100	Operations	Chris McCowage
	1200	IT	Chris Ramage
	1230	Lunch with Coonabarabran staff	
	1330	Discussion	Coonabarabran staff
	1400	Discussion with Director, RSAA	Penny Sackett
	1500	Tour of UKST and other SSO facilities	Penny Sackett/Matthew Colless
	1600	Discussion with Coonababran leaders	Mayor, Shire President, the Hon George Souris MP
12 Apr	0900	Panel discussion	
	1000	Tour of Epping facilities	Matthew Colless
	1030	Morning tea with Instrumentation and Instrument Science staff	
	1100	Discussion	Instrumentation and Instrument Science staff
	1130	Discussion with Australian members of the AAT Board	Warrick Couch, Brian Schmidt, Greg Harper
	1230	Lunch with AAT Board	
	1330	Discussion with Australian members of AAOUC and AATAC, and President of ASA	AAOUC, AATAC, Gary Da Costa
	1430	Panel discussion	
	1530	Afternoon tea with Astronomy staff	
	1600	Discussion	Astronomy staff
	1630	Panel discussion	
13 Apr	0900	The UKST	Fred Watson
	0930	Education and outreach	Fred Watson
	1000	Final discussion with AAO management	Matthew Colless and Neville Legg
	1100	Economic impact analysis	David Campbell (ACIL Tasman)
	1200	Panel discussion	

Appendix 6

Anglo-Australian Observatory's preferred budgets

Table 2: Base scenario

Income ($ million)	***2005-06***	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2006-2011**
AU recurrent	*4.6*	4.7	4.8	4.9	5.0	5.1	**24.5**
UK recurrent	*3.7*	1.9	0.6	0.6	0.6	0.0	**3.7**
Additional AU recurrent	*0.0*	0.1	1.5	1.5	1.8	2.5	**7.4**
AusGO recurrent	*0.0*	0.3	0.5	0.5	0.5	0.5	**2.3**
Total recurrent	***8.3***	***7.0***	***7.4***	***7.5***	***7.9***	***8.1***	***37.9***
AAT refurbishment	*0.0*	1.1	1.0	1.0	1.0	0.0	**4.1**
New AAT instrument	*0.0*	0.7	1.4	0.8	0.0	0.0	**2.9**
Total capital	***0.0***	***1.8***	***2.4***	***1.8***	***1.0***	***0.0***	***7.0***
WFMOS	*0.5*	1.0	1.0	2.0	3.0	3.0	**10.0**
ELT instruments	*0.0*	0.0	0.0	0.0	0.0	0.0	**0.0**
RAVE	*0.5*	0.5	0.5	0.6	0.6	0.0	**2.2**
Other external	*1.4*	0.5	0.5	0.5	0.5	0.5	**2.5**
Total external	***2.4***	***2.0***	***2.0***	***3.1***	***4.1***	***3.5***	***14.7***
Grand total	***10.7***	**10.8**	**11.8**	**12.4**	**13.0**	**11.6**	**59.6**

Expenditure ($ million)	***2005-06***	**2006-07**	**2007-08**	**2008-09**	**2009-10**	**2010-11**	**2006-2011**
AAT operations	*3.1*	3.2	3.3	3.4	3.5	3.6	**17.0**
Gemini/8m support	*0.0*	0.3	0.5	0.5	0.5	0.6	**2.4**
Instrumentation core	*2.0*	2.0	2.1	2.1	2.2	2.2	**10.6**
Computing & IT	*0.7*	0.5	0.5	0.5	0.6	0.6	**2.7**
Corporate	*1.8*	1.0	1.0	1.0	1.1	1.1	**5.2**
Total recurrent	***7.6***	***7.0***	***7.4***	***7.5***	***7.9***	***8.1***	***37.9***
AAT refurbishment	*0.0*	1.1	1.0	1.0	1.0	0.0	**4.1**
New AAT instrument	*0.0*	0.7	1.4	0.8	0.0	0.0	**2.9**
Total capital	***0.0***	***1.8***	***2.4***	***1.8***	***1.0***	***0.0***	***7.0***
WFMOS	*2.3*	1.0	1.0	2.0	3.0	3.0	**10.0**
ELT instruments	*0.0*	0.0	0.0	0.0	0.0	0.0	**0.0**
RAVE	*0.5*	0.5	0.5	0.6	0.6	0.0	**2.2**
Other external	*0.0*	0.5	0.5	0.5	0.5	0.5	**2.5**
Total external	***2.8***	***2.0***	***2.0***	***3.1***	***4.1***	***3.5***	***14.7***
Grand total	***10.4***	**10.8**	**11.8**	**12.4**	**13.0**	**11.6**	**59.6**

Notes

- All amounts are indexed; in 2005-06 dollars the total AU recurrent income is $6.9 million.
- Other external revenue includes: FMOS $0.64 million; sale of AATB house $0.13 million; OPTICON fees $0.52 million.
- OH&S remedial works: prepayment of $2.7 million received in 2005-06 for works over 2006-2008.

Table 3: AAO's alternative scenario – Panel recommended

Income ($ million)	*2005-06*	2006-07	2007-08	2008-09	2009-10	2010-11	2006-2011
AU recurrent	*4.6*	4.7	4.8	4.9	5.0	5.1	**24.5**
UK recurrent	*3.7*	1.9	0.6	0.6	0.6	0.0	**3.7**
Additional AU recurrent	*0.0*	0.2	1.8	2.1	2.8	3.8	**10.7**
AusGO recurrent	*0.0*	0.3	0.5	0.5	0.5	0.5	**2.3**
Total recurrent	***8.3***	***7.1***	***7.7***	***8.1***	***8.9***	***9.4***	***41.2***
AAT refurbishment	*0.0*	1.1	1.0	1.0	1.0	0.0	**4.1**
New AAT instrument	*0.0*	0.7	1.4	0.8	0.0	0.0	**2.9**
Total capital	***0.0***	***1.8***	***2.4***	***1.8***	***1.0***	***0.0***	***7.0***
WFMOS	*0.5*	1.0	0.0	0.0	0.0	0.0	**1.0**
ELT instruments	*0.0*	0.1	0.3	0.7	1.0	1.9	**4.0**
RAVE	*0.5*	0.5	0.5	0.6	0.6	0.0	**2.2**
Other external	*1.4*	0.5	0.5	0.5	0.5	0.5	**2.5**
Total external	***2.4***	***2.1***	***1.3***	***1.8***	***2.1***	***2.4***	***9.7***
Grand total	***10.7***	**11.0**	**11.4**	**11.7**	**12.0**	**11.8**	**57.9**

Expenditure ($ million)	*2005-06*	2006-07	2007-08	2008-09	2009-10	2010-11	2006-2011
AAT operations	*3.1*	3.2	3.3	3.4	3.5	3.6	**17.0**
Gemini/8m support	*0.0*	0.3	0.5	0.5	0.5	0.6	**2.4**
Instrumentation core	*2.0*	2.0	2.1	2.1	2.2	2.2	**10.6**
Computing & IT	*0.7*	0.5	0.5	0.5	0.6	0.6	**2.7**
Corporate	*1.8*	1.0	1.0	1.0	1.1	1.1	**5.2**
Total recurrent	***7.6***	***7.0***	***7.4***	***7.5***	***7.9***	***8.1***	***37.9***
AAT refurbishment	*0.0*	1.1	1.0	1.0	1.0	0.0	**4.1**
New AAT instrument	*0.0*	0.7	1.4	0.8	0.0	0.0	**2.9**
Total capital	***0.0***	***1.8***	***2.4***	***1.8***	***1.0***	***0.0***	***7.0***
WFMOS	*2.3*	1.0	0.0	0.0	0.0	0.0	**1.0**
ELT instruments	*0.0*	0.2	0.6	1.3	2.0	3.2	**7.3**
RAVE	*0.5*	0.5	0.5	*0.6*	0.6	0.0	**2.2**
Other external	*0.0*	0.5	0.5	0.5	0.5	0.5	**2.5**
Total external	***2.8***	***2.2***	***1.6***	***2.4***	***3.1***	***3.7***	***13.0***
Grand total	***10.4***	**11.0**	**11.4**	**11.7**	**12.0**	**11.8**	**57.9**

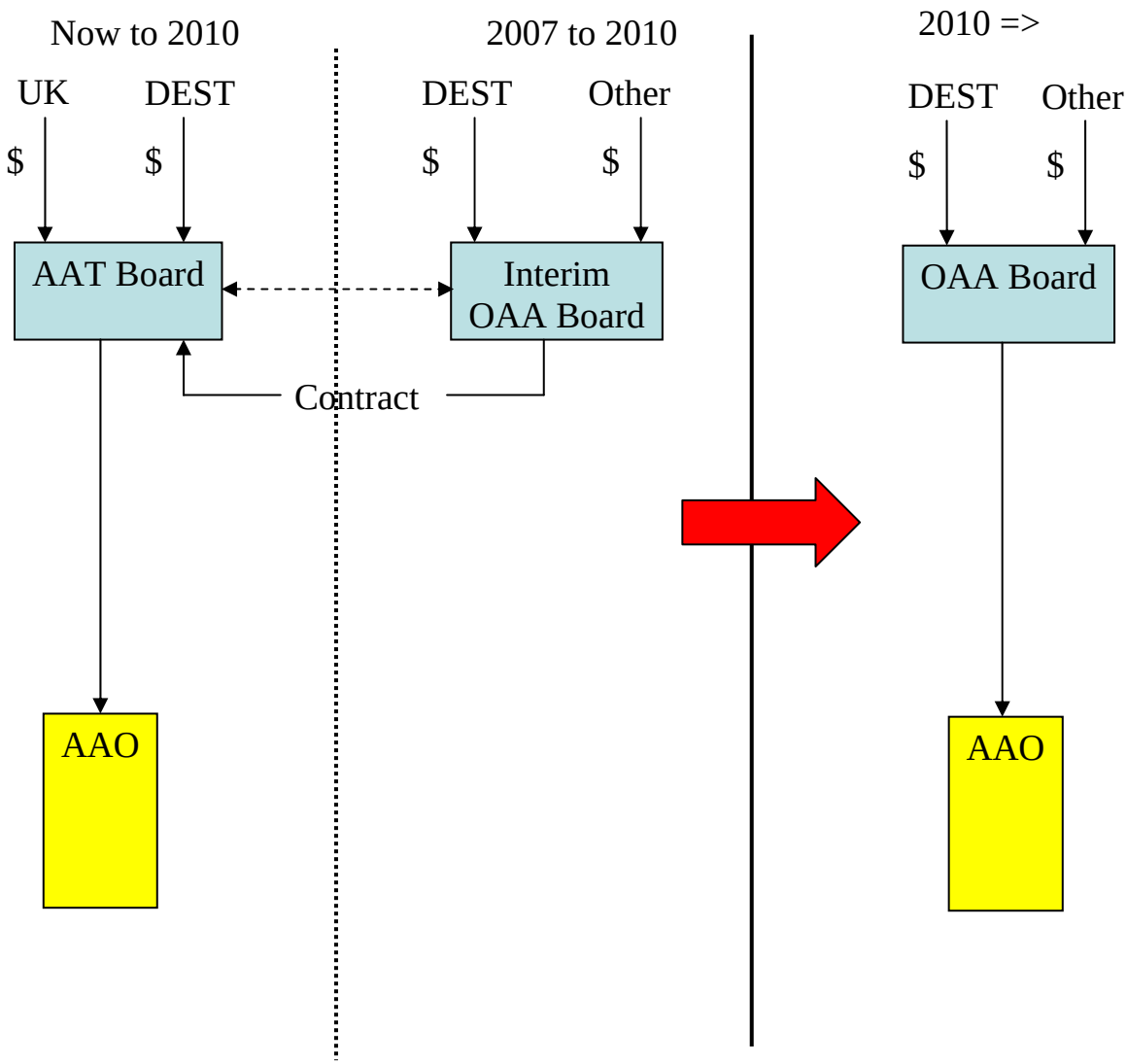
Notes

- All amounts are indexed; in 2005-06 dollars the total AU recurrent income is $8.1 million.
- Other external revenue includes: FMOS $0.64 million; sale of AATB house $0.13 million; OPTICON fees $0.52 million.
- OH&S remedial works: prepayment of $2.7 million received in 2005-06 for works over 2006-2008.

Appendix 7

Figure 1

Optical Astronomy Australia Governance



Glossary

2dF	Two-degree Field fibre spectrograph on the AAT
6dF	Six-degree Field fibre spectrograph on the UKST
AAO	Anglo-Australian Observatory
AAOmega	New fibre spectrograph on the AAT
AAOmicron	Proposed new fibre-fed near-infrared spectrograph for the AAT
AAOUC	AAO Users' Committee
AAT	Anglo-Australian Telescope
AATAC	Anglo-Australian Time Assignment Committee
AATB	Anglo-Australian Telescope Board
ALMA	Atacama Large Millimeter Array (radio)
Antarctic	PILOT – Pathfinder for an International Large Optical Telescope (proposed 2-m telescope for Dome C in Antarctica)
ASA	Astronomical Society of Australia
ATNF	Australia Telescope National Facility
AusGO	Australian Gemini Office
CSIRO	Commonwealth Scientific and Industrial Research Organisation
ELT	Extremely Large Telescope (optical/infrared)
ESO	European Southern Observatory
FMOS/Echidna	Fibre positioner being built by AAO for a near-infrared spectrograph on the Japanese Subaru 8-m telescope
Gemini	Gemini Telescopes (twin 8-m telescopes in Hawaii and Chile)
NCRIS	National Collaborative Research Infrastructure Strategy
OAAB	Optical Astronomy Australia Board
OH suppression	Use of optical fibres with embedded diffraction gratings to remove hydroxyl atmospheric emission lines in near infrared
Optical/IR	Optical/infrared astronomy
OzPoz	Fibre positioner built by the AAO for ESO Very Large Telescope in Chile
RAVE	Radial Velocity Experiment (survey using 6dF on UKST)
RSAA	Research School of Astronomy and Astrophysics, Australian National University
SKA	Square Kilometre Array (next generation radio telescope)
SSO	Siding Spring Observatory
Starbug	Autonomous focal plane device developed by AAO
Subaru	Japanese National Large Telescope (8-m) in Hawaii
UKST	UK Schmidt Telescope (AAO's 1.2-m wide-field telescope)
WFMOS	Wide-Field Multi Object Spectrograph for Gemini/Subaru