Australian Government

Department of Education, Science and Training

REVIEW OF THE ANGLO-AUSTRALIAN OBSERVATORY

ISSUES PAPER

AAO REVIEW PANEL

FEBRUARY 2006

SECTION 1 BACKGROUND ON THE REVIEW

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. The Review will report to the Hon Julie Bishop MP, now Minister for Education, Science and Training.

1.1 Terms of reference

The Review's terms of reference are 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[1], 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 (*see below for context*);
  - 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.

<u>Supplementary Agreement</u>

In 2005 the UK and Australian governments agreed to amend the *Anglo-Australian Telescope Agreement*, through a Supplementary Agreement[2], to provide for the current collaboration

[1] *New Horizons: A Decadal Plan for Australian Astronomy 2006-2015* was prepared by the research community (represented by the National Committee for Astronomy of the Australian Academy of Science) in November 2005.

[2] The Anglo-Australian Telescope Agreement is a treaty between the governments of Commonwealth of Australia and the United Kingdom of Great Britain and Northern Ireland. The Supplementary Agreement was signed on 3 November 2005. It is scheduled to enter into force in early 2006 when required legislative amendments are passed by the Australian Parliament and final diplomatic processes are completed.

between the UK and Australia to end on 30 June 2010. At that time the Anglo-Australian Telescope (AAT) and associated facilities will transfer to Australian ownership and control.

1.2 Arrangements for the Review

Review panel

The Review will be conducted by a three person Review panel:

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 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.

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.

Invitation to make submissions to the Review

The Review panel invites written submissions from:

- astronomers who have conducted research using AAO facilities;
- external clients of the AAO's instrumentation programme;
- organisations associated with the AAO; particularly those involved in collaborative research or instrument development activity;
- people or organisations able to provide a broad perspective on issues relevant to the Review; and
- interested members of the public.

While submissions may address any matters respondents wish, the panel would particularly welcome input on the issues raised in this paper.

Timetable for the Review

The Review will be conducted during the first half of 2006.

The closing date for written submissions to the Review is **24 March 2006**.

Between February and April 2006 the Review panel will gather and consider various evidence on the AAO's scientific and operational outcomes.

In April 2006 the Review panel will consider written submissions and convene to:

- make site visits to inspect the AAO's facilities and services;
- meet with AAT Board members and the management and staff of the AAO; and
- hold public meetings for interested parties if warranted.

The Review panel expects to produce its report for consideration by the Minister by June 2006.

2 BACKGROUND ON THE AAO

2.1 History of the AAO

On 25 September 1969 the governments of the United Kingdom and Australia signed the *Anglo-Australian Telescope Agreement* ('the Agreement') to build and operate the Anglo-Australian Telescope (AAT) at Siding Spring near Coonabarabran in New South Wales.

Planning for the AAT commenced in 1967. It was decided that the AAT would be a 3.9m telescope similar to the 4m telescope of the Kitt Peak National Observatory in the United States. The telescope was commissioned in late 1974 and commenced scientific operations in 1975.

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.

In 1974 the AATB 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 1.2m UK Schmidt Telescope, operated by the Royal Observatory, Edinburgh, was brought under the control of the AATB.

AAO Purpose Statement

The Anglo-Australian Observatory (AAO) provides world-class optical and infrared observing facilities enabling Australian and British astronomers to do excellent science. The AAO is a world leader in astronomical research and in the development of innovative telescope instrumentation. It also takes a leading role in the formulation of long-term plans for astronomy in Australia and the United Kingdom.

2.2 The Board and organisational/funding arrangements

The Anglo-Australian Telescope Board is the body responsible for managing and operating the AAO. The Board is a statutory authority established under Australian law (by the *Anglo-Australian Telescope Agreement Act 1970*) and operates as a bi-national body in accordance with the *Anglo-Australian Telescope Agreement*.

The Board is responsible to the Australian Minister for Education, Science and Training and the United Kingdom Secretary of State for Trade and Industry.

The Board has broad powers under the Agreement to determine the strategic direction and scientific programme of the AAO and to employ staff and manage finances. Under the original Agreement:

- the UK and Australia are equally represented on the Board;
- the AAT (and by extension the AAO) are jointly and equally owned and funded by Australia and the UK (technically the AAT is owned by the AATB as the legal entity); and
- observing time is shared equally by the parties.

In addition to providing for the Anglo-Australian Telescope Agreement to end on 20 June 2010, the Supplementary Agreement signed on 3 November 2005 will introduce, when it enters into force in 2006, new funding and time allocation arrangements. Under the new arrangements

each country will determine the level of its contribution (above a minimum level) and time will be allocated to each country on a *pro-rata* basis according to financial contributions.

The AAO has annual revenues of around A$9.5 million[3]. Around 80% of the AAO's revenue is derived from financial contributions and grants from the two governments. The remaining 20% comes from AAO operations (largely external instrumentation contracts).

The operations and budget of the AAO are managed by the Director, a Board appointee who is responsible to the Board. The Director is assisted by a small administrative staff. Scientific and instrument programmes and telescope operations are supported by:

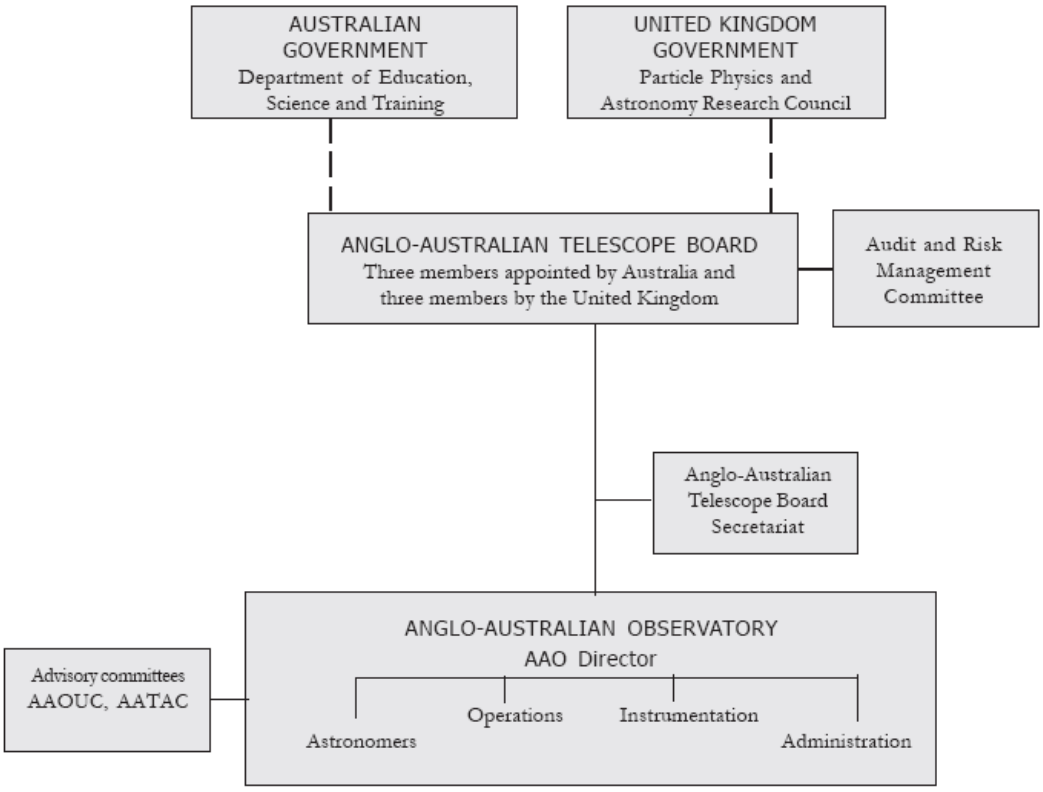
- 12 support astronomers and night assistants;
- 18 technical and engineering support staff; and
- 25 instrumentation development staff.

Two main advisory committees contribute to the operations of the AAO, namely:

- 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 Board is required under the *Anglo-Australian Telescope Agreement Act 1970* to report annually to the Australian Parliament (through its annual report and financial statements).

Figure 1.1 General structure of the AAO



[3] $9.685 million in 2004/05, following $9.450 million in 2003/04 – *AAO Annual Report 2004-05.*

3. PERFORMANCE OF THE AAO

The Review will evaluate the efficiency and effectiveness of the AAO in delivering its facilities and services, scientific outcomes, the instrumentation programme, education and outreach programmes and in management and governance. This is the first major Australian performance evaluation of the AAO and will focus on the last five years of operations.

3.1 Facilities and services

The AAO was established to provide world-class observing facilities and services to the Australian, British and international astronomy communities. It aims to provide access at a reasonable cost but with a high level of technical and scientific support to maximise observing outcomes and efficiency.

Each semester, the AAO provides observing time to 50 to 60 research programmes. These programmes involve between 150 and 250 astronomers. Around 80% of the observing time is shared by Australian and UK astronomers and the other 20% is used by astronomers from other countries. Time on the AAT is typically oversubscribed by a factor of 2 to 2.5. Appendix 1 provides more details on usage of the AAT.

A major focus of the AAO is to keep the telescopes internationally competitive through instrumentation development and innovation. Around 15% of the AAO budget is allocated to new instruments and associated software and detectors.

The Review panel will evaluate the AAO's facilities and services by:

- visiting and inspecting AAO sites;
- analysing data from user surveys undertaken by the AAO over a number of years;
- analysing data on users and use of the AAO; and
- consideration of submissions from telescope users and other stakeholders.

Issues - Facilities and services

Key issues for this section of the Review are:

- the quality of facilities and support provided to AAO users, including IT support;
- productivity of the AAO including comparative cost of telescope time;
- how the AAO compares to similar observatories in terms of facilities and services;
- the likely lifetime of the AAO as a frontline research facility; and
- issues or problems (current and emerging) with supporting and updating facilities and the provision of services.

3.2 Scientific outcomes

The AAO's Statement of Purpose says that: "The AAO is a world leader in astronomical research and in the development of innovative telescope instrumentation."

In the past five years, key areas of research using the AAO's facilities have included cosmology and the large-scale structure of the universe, galaxy evolution and the properties of nearby galaxies, stellar motions in the Milky Way, the detection of extra-solar planets, and pioneering work in asteroseismology. These key research areas have exploited the AAO's strengths in wide-field, multi-object spectroscopy, near-infrared imaging and spectroscopy, and extremely stable high-resolution spectroscopy.

In evaluating the AAO's scientific outcomes over the past five years, the Review will consider:

- a selection of scientific papers, as nominated by the AAO, produced by both AAO-based astronomers and external users of the AAO. Appendix 2 provides details of the papers nominated for peer Review;

- data on publication of papers linked to the AAO and their impact on astronomy literature. Appendix 3 provides a compilation of the bibliometric data to be analysed; and

- written submissions from stakeholders and interested parties addressing the issues below.

Issues - Scientific outcomes

Key issues for this section of the Review are:

- the level of scientific impact achieved by the AAO (both in terms of the AAO's own research programmes and the AAO as a facility for the Australian astronomical community);

- the strengths and weaknesses of the AAO's research programme;

- the strengths and weaknesses of the AAO's scientific infrastructure; and

- the extent of international collaboration evident in AAO-supported research.

3.3 Instrumentation programme

The AAO's instruments have been developed in-house through the AAO's instrument science programme or in collaboration with Australian or British institutions. A number of instruments have also been developed, or are being developed, for other observatories. See Appendix 4 for background on recent AAO instrumentation projects.

The instrument science group at the AAO:

- develops new astronomical instrumentation techniques and related science;

- provides scientific and engineering support to AAO instrumentation projects;

- acts as an 'interface' between scientists and engineering staff on instrument development; and

- seeks to advance astronomical technologies to keep the AAO internationally competitive.

In evaluating the AAO's instrumentation programme, the Review panel will consider:

- user survey data collected by the AAO;
- other performance and outcomes data for AAO-developed instruments; and
- submissions from AAO users and external clients of the programme.

Issues – Instrumentation programme

Key issues for this section of the Review are:

- the overall quality of AAO developed instruments;
- contributions made by the AAO to astronomical technology and innovation;
- contributions by the AAO instrument programme to Australian technology and industry development more generally; and
- the degree of 'customer' satisfaction with externally-contracted AAO instruments in terms of innovation, cost effectiveness, timeliness of delivery, quality and support.

3.4 Education and outreach programmes

The AAO has an important role in the training of astronomy students in Australia and the UK and in public education about astronomy.

The AAO maintains a website and publishes a newsletter three times a year. AAO staff are also involved in a range of outreach activities. Background and data on the AAO's research student outcomes is at Appendix 5.

In evaluating the AAO's education and outreach programmes, the Review will consider:

- data on research training and outreach programme outputs (for example research student commencements and completions, press mentions, interviews and events);
- qualitative data on education outcomes; and
- submissions addressing the issues outlined below.

Issues – Education and outreach

Key issues for this section of the Review are:

- the appropriate role of the AAO in research training and outreach;
- the broad contribution made by the AAO to the national economy of the postgraduate research training supported by the AAO;

- the effectiveness of the AAO's contribution to research training and outreach; and

- the degree of success in promoting the outcomes of Australian science and astronomy internationally and encouraging an interest in astronomy and science in the community.

3.5 Management and governance

The AATB has overall responsibility, on behalf of the Australian and UK governments, for the operation and management of the AAO. The primary purpose of the AAO is to provide internationally competitive optical/infrared astronomical facilities and services to the Australian and UK scientific communities.

In evaluating the management and governance of the AAO, the Review will:

- consider submissions from AAO users and other stakeholders, particularly on the issues listed below;

- have discussions with the Board and management team; and

- consider the broad outcomes achieved by the AAO in each of its areas of operation.

Issues – management and governance

Key issues for this section of the Review are:

- Leadership and direction provided by the Board and the AAO Director to the development of the facility and its associated research programmes;

- how effectively have resources been managed to maintain the research programme, services to external users, investment in the facilities and instruments, supporting infrastructure, the education programme and administration; and

- the appropriateness and effectiveness of the governance arrangements, including how effectively the AATB and management have responded to opportunities and threats.

4. FUTURE ROLE AND ARRANGEMENTS FOR THE AAO

The Review has been tasked to advise the Minister on the future role of the AAO and appropriate organisational, governance and funding arrangements for the AAO as it makes the transition from a bi-national facility to a wholly Australian owned and operated facility.

4.1 Enhancing the performance of the AAO

In making its recommendations, the Review will consider:

- the relationship between the AAO and the *Decadal Plan for Australian Astronomy 2005-2016*;

- developments in astronomy infrastructure internationally and Australia's likely or possible role in them;

- opportunities and threats likely to emerge in the period leading up to the end of the *Anglo-Australian Telescope Agreement* in July 2010, such as:

    - the need to clarify the long-term status of the AAO to enable it to enter into long-term contracts (for example AAO involvement in the Gemini WFMOS project if it proceeds beyond the conceptual design phase); and

    - the likely financial position of the AAO through the remainder of the *Anglo-Australian Telescope Agreement* and the likely costs of maintaining, upgrading and running the facility.

Issues – enhancing the performance of the AAO

Key issues for the Review in making its recommendations include:

- the need for possible refinement of the strategic direction and role of the AAO;

- options for upgrading facilities and services;

- options for developing the instrumentation programme and technology innovation;

- the need to address any scientific weakness and develop scientific strengths;

- options for improving the AATB/AAO's management and governance; and

- options for developing the AAO's relationship with government and other stakeholders.

4.2 Funding and governance/organisational arrangements post July 2010

The Minister has asked the Review to advise on issues and options related to the transfer of ownership and control of the AAO to Australia in July 2010.

The Review will consider the relative merits and appropriateness of a range of potential governance/organisational models including:

- re-establishing the AAO as an independent national facility (with independent AATB-like board);
- amalgamation with an existing organisation such as CSIRO Australia Telescope National Facility or the Research School of Astronomy and Astrophysics (RSAA), ANU;
- establishing an AURA-like organisation to own and operate the facilities; and
- other possible options such as another international partnership.

Issues – possible governance/organisational models for post July 2010

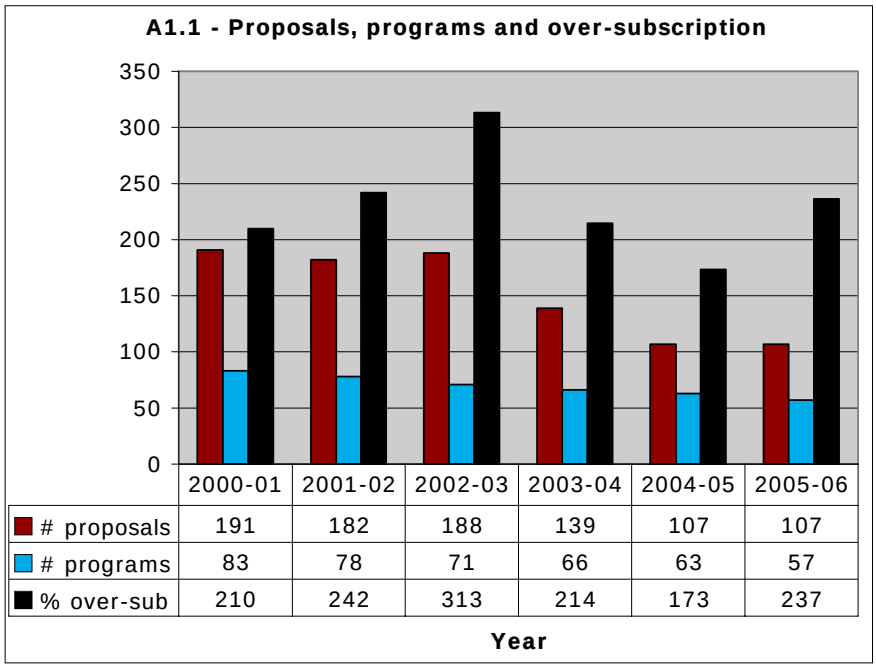
The Review will consider and weigh the following:

- the scope for a national optical/IR astronomy facility in Australia after July 2010, taking into account its strategic positioning in relation to other astronomy facilities in which Australia is involved internationally;
- the optimal governance/organisational arrangements for a national facility taking into account issues such as:
  - the need to balance the independence of a national facility with close involvement by users and stakeholders;
  - possible synergies with other organisations and facilities such as the Australian Gemini Office, the Australia Telescope National Facility, the Research School of Astronomy and Astrophysics, ANU, and other universities (with special reference to the facilities and organisations also located at Epping and Siding Spring); and
  - the funding requirement for the post-2010 arrangement and possible funding models and sources (such as the extension of budget funding, research grant funding or partner contributions).

APPENDIX 1

USE OF THE AAT

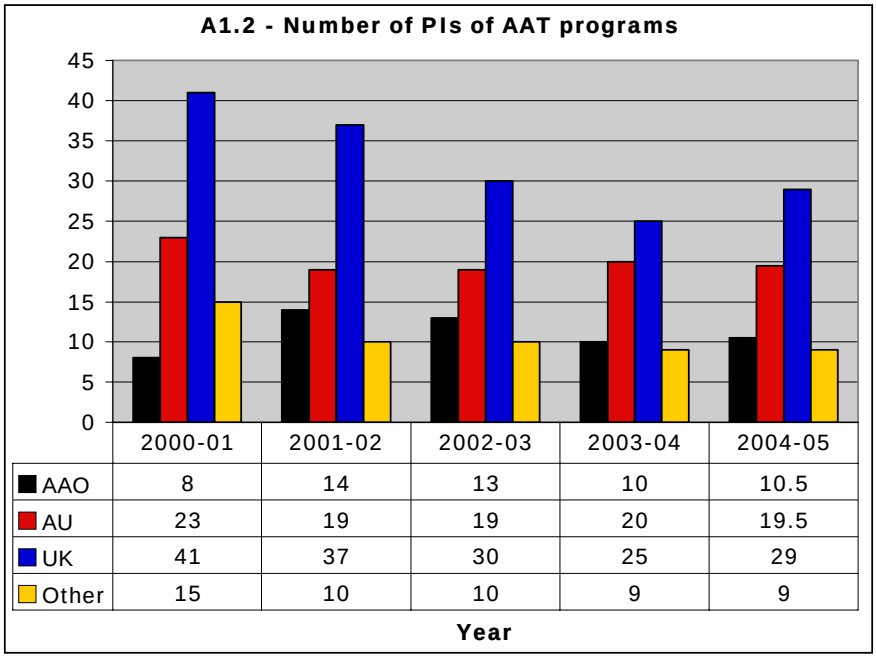
Table A1.1 shows the number of AAT proposals, the number of programmes awarded time, and the over-subscription rate for each of the last five years and the coming year. Over-subscription is defined as the total requested number of nights divided by the available number of nights on the AAT.



	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
# proposals	191	182	188	139	107	107
# programs	83	78	71	66	63	57
% over-sub	210	242	313	214	173	237

The numbers of proposals and programmes have decreased, but the over-subscription has remained fairly constant, with an average of 235%. This reflects a trend towards a smaller number of larger programmes on the AAT.

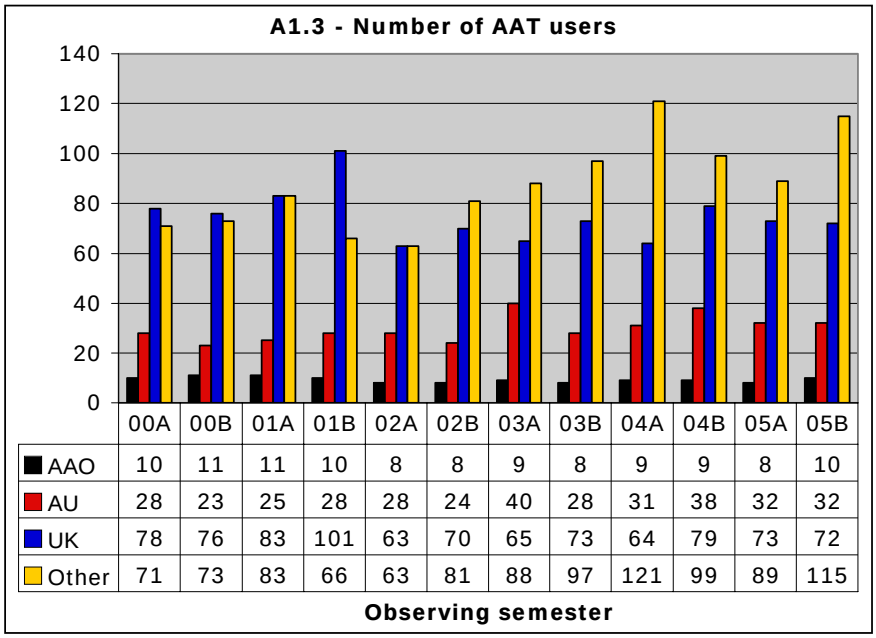
Table A1.2 shows the numbers of PIs (Principal Investigators) from the AAO, Australia, the UK and other countries who were awarded time in each year over the period 2000-2005.



	2000-01	2001-02	2002-03	2003-04	2004-05
AAO	8	14	13	10	10.5
AU	23	19	19	20	19.5
UK	41	37	30	25	29
Other	15	10	10	9	9

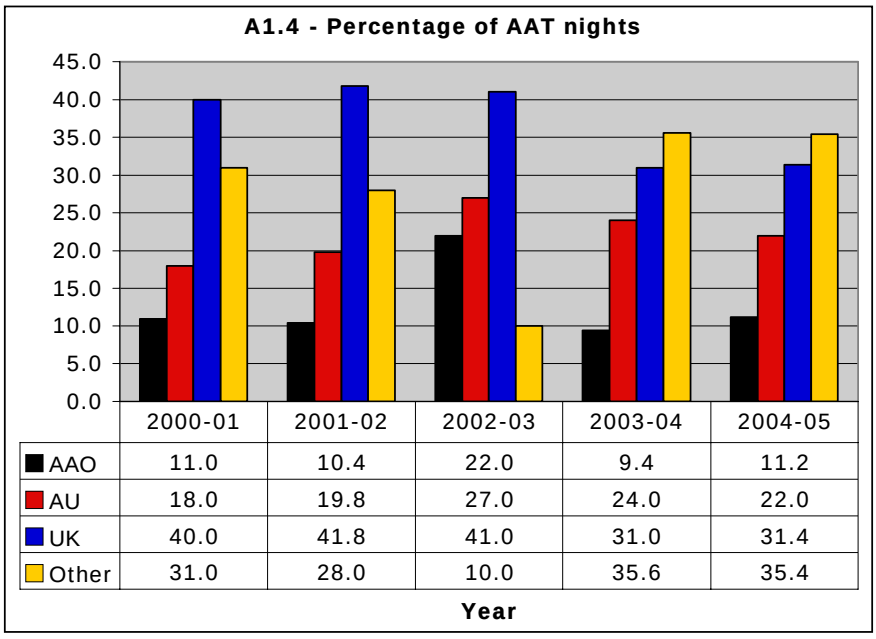
The UK has the largest number of PIs, but the combined total of Australian and AAO PIs has exceeded the number of UK PIs in recent years. Over the last three years the distribution has been roughly constant, with the fractions of AAO, Australian, UK and other PIs being about 15%, 30%, 40% and 15%.

Another view of AAT use is provided by the total number of people on proposals awarded time. Table A1.3 gives the numbers of AAO, Australian, UK and other users in each semester over the period 2000-2005.



	00A	00B	01A	01B	02A	02B	03A	03B	04A	04B	05A	05B
AAO	10	11	11	10	8	8	9	8	9	9	8	10
AU	28	23	25	28	28	24	40	28	31	38	32	32
UK	78	76	83	101	63	70	65	73	64	79	73	72
Other	71	73	83	66	63	81	88	97	121	99	89	115

Australian users have increased mildly over this period and recently have been in the range 30-40 per semester; AAO users have been approximately constant at around 10 per semester. Use by UK astronomers dropped slightly early in the period but recently has recovered to around 70 per semester. The strongest trend is in the increasing number of users from other countries, reflecting increasing international collaboration.

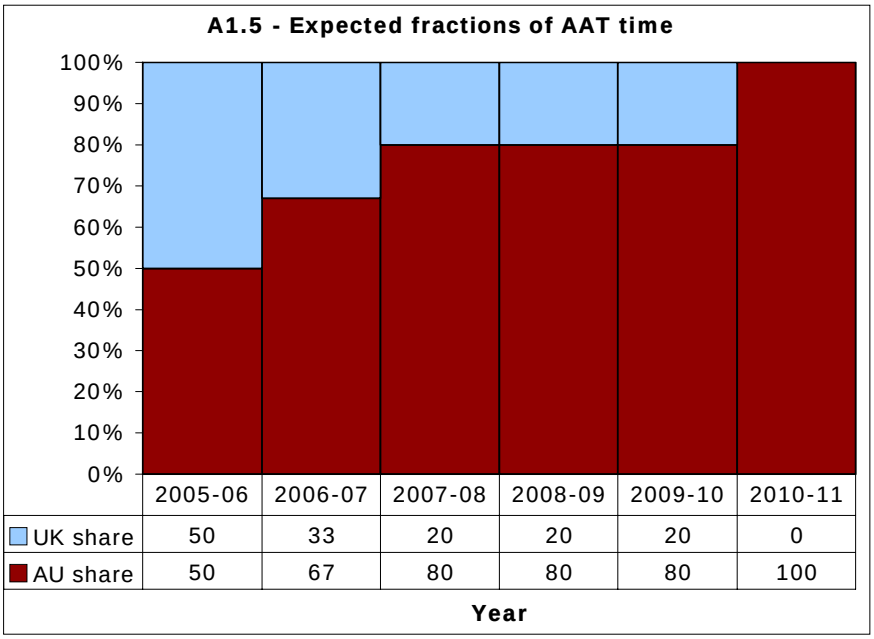


	2000-01	2001-02	2002-03	2003-04	2004-05
AAO	11.0	10.4	22.0	9.4	11.2
AU	18.0	19.8	27.0	24.0	22.0
UK	40.0	41.8	41.0	31.0	31.4
Other	31.0	28.0	10.0	35.6	35.4

Table A1.4 shows the percentage use of the AAT, in terms of nights allocated to users from the AAO, Australia, the UK and other countries over 2000-2005. Over this period, the fraction of

nights obtained by AAO users has been constant at around 10%, the fraction obtained by Australian users has increased slightly to 20-25%, the UK fraction has decreased from 40% to 30%, and the fraction going to others has fluctuated considerably but is currently around 35%.

All of these usage statistics are likely to change markedly over the next five years as the fraction of time available to Australian astronomers increases and the fraction available to UK astronomers decreases, due to decreasing UK recurrent funding. Table A1.5 shows the expected fractions of AAT time for Australian and UK astronomers based on the predicted recurrent funding contributions to the AAO by both countries. Note, however, that the actual shares of time depend on the total contributions by both countries, including grants and contracts, and so will differ at some level from this prediction.



	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
UK share	50	33	20	20	20	0
AU share	50	67	80	80	80	100

Additional information and statistics on the use of the AAT can be found in the AAO Annual Reports (see http://www.aao.gov.au/annual/).

APPENDIX 2

SCIENTIFIC PAPERS FOR EVALUATION

Twenty-five papers have been selected for review – five from each year in the period 2000-2004. In each year, at least two were selected as having AAO staff as lead authors and containing data from any facility **(AAO),** and a further two or more were selected as having Australian non-AAO staff as lead authors and based on AAO data **(AUS)**; note that affiliations are those at the date of publication. It should also be noted that there are many papers based on data from AAO facilities that have significant AAO and/or Australian authorship but do not fall into either of these categories.

These 25 papers were selected to not only highlight highly-cited publications arising from the AAO, but also to show the breadth of science carried out with AAO facilities and by AAO staff, as well as the broad user base that AAO's facilities support across Australia. These papers represent the full spectrum of astronomical results – from the results of major surveys probing the fundamental structure of the universe, to the discovery of new classes of galaxies and exoplanets orbiting other stars. They also include papers describing the results of radical new observing techniques pioneered by AAO staff and influential reviews of astronomical sub-disciplines that have changed the way in which astronomy has moved forward.

These papers have appeared in high-quality, high-impact journals – *Nature* (1 paper, ISI impact factor=32.2), *Science* (1 paper, impact factor=31.9), *Annual Reviews of Astronomy & Astrophysics* (1 paper, impact factor=18.8) *Astrophysical Journal* (5 papers, impact factor=6.24), *Astronomical Journal* (2 papers, impact factor=5.84), *Monthly Notices of the Royal Astronomical Society* (17 papers, impact factor=5.24), *Publications of the Astronomical Society of the Pacific* (1 paper, impact factor=3.90)*, Publications of the Astronomical Society of Australia* (1 paper, impact factor=1.1). The preponderance of papers in *Monthly Notices* is largely driven by economics – it is the only major, high-quality astronomical journal that does not levy page charges. The citation counts reported for each paper are from the ISI Web of Science and the Smithsonian/NASA Astrophysical Data System Abstracts Service as at 17 January 2006 (in the format *ISI / ADS*)

2000

[1] **AAO:** Boyle, BJ; Shanks, T; Croom, SM; Smith, RJ; Miller, L; Loaring, N; Heymans, C. 2000, *MNRAS,* 317, 1014-1022.
The 2dF QSO Redshift Survey - I. The optical luminosity function of quasi-stellar objects
Times Cited: 189 / 229

[2] **AUS:** Drinkwater, MJ; Jones, JB; Gregg, MD; Phillipps, S. 2000, *PASA* 17, 227-233
Compact stellar systems in the Fornax Cluster: Super-massive star clusters or extremely compact dwarf galaxies?
Times Cited: 32 / 44

[3] **AUS:** Kilborn, VA; Staveley-Smith, L; Marquarding, M; Webster, RL; Malin, DF; Banks, GD; Bhathal, R; de Blok, WJG; Boyce, PJ; Disney, MJ; Drinkwater, MJ; Ekers, RD; Freeman, KC; Gibson, BK; Henning, PA; Jerjen, H; Knezek, PM; Koribalski, B; Minchin, RF; Mould, JR; Oosterloo, T; Price, RM; Putman, ME; Ryder, SD; Sadler, EM; Stewart, I; Stootman, F; Wright, AE. 2000, *AJ,* 120, 1342-1350
An extragalactic HI cloud with no optical counterpart?
Times Cited: 24 / 36

[4] **AAO:** Bland-Hawthorn, J; Freeman, K. 2000, *Science,* 287, 79-84
The baryon halo of the Milky Way: A fossil record of its formation
Times Cited: 9 / 11

[5] **AUS:** Lee, JK; Burton, MG. 2000, *MNRAS,* 315, 11-20
An infrared proper motion study of the Orion bullets
Times Cited: 17 / 17

2001

[6] **AUS:** Colless, M; Dalton, G; Maddox, S; Sutherland, W; Norberg, P; Cole, S; Bland-Hawthorn, J; Bridges, T; Cannon, R; Collins, C; Couch, W; Cross, N; Deeley, K; De Propris, R; Driver, SP; Efstathiou, G; Ellis, RS; Frenk, CS; Glazebrook, K; Jackson, C; Lahav, O; Lewis, I; Lumsden, S; Madgwick, D; Peacock, JA; Peterson, BA; Price, I; Seaborne, M; Taylor, K. 2001, *MNRAS* 328, 1039-1063
The 2dF Galaxy Redshift Survey: spectra and redshifts
Times Cited: 330 / 411

[7] **AAO:** Croom, SM; Shanks, T; Boyle, BJ; Smith, RJ; Miller, L; Loaring, NS; Hoyle, F. 2001, *MNRAS,* 325, 483-496
The 2dF QSO Redshift Survey - II. Structure and evolution at high redshift
Times Cited: 44 / 52

[8] **AAO:** Tinney, CG; Butler, RP; Marcy, GW; Jones, HRA; Penny, AJ; Vogt, SS; Apps, K; Henry, GW. 2001, *ApJ,* 551, 507-511
First results from the Anglo-Australian Planet Search: A brown dwarf candidate and a 51 peg-like planet
Times Cited: 39 / 41

[9] **AUS:** Bedding, TR; Butler, RP; Kjeldsen, H; Baldry, IK; O'Toole, SJ; Tinney, CG; Marcy, GW; Kienzle, F; Carrier, F. 2001, *ApJL,* 549, L105-L108
Evidence for solar-like oscillations in beta Hydri
Times Cited: 32 / 46

[10] **AAO:** Glazebrook, K; Bland-Hawthorn, J. 2001, *PASP* 113, 197-214
Microslit nod-shuffle spectroscopy: A technique for achieving very high densities of spectra
Times Cited: 24 / 34

2002

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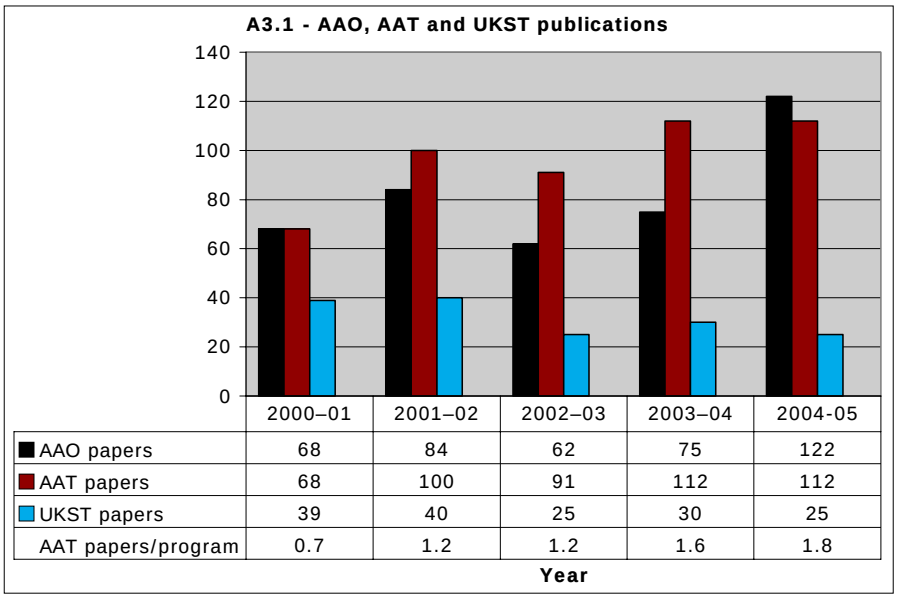
APPENDIX 3

BIBLIOMETRIC DATA

Figure A3.1 gives the numbers of publications over the past five years by AAO astronomers (including staff, emeritus staff, students and visitors) and the numbers of publications based substantially on data obtained with the AAT or the UK Schmidt Telescope (UKST). These publications include papers in refereed journals and conference proceedings. The table also gives the number of AAT publications in each year relative to the number of programmes allocated time in the previous year.



	2000–01	2001–02	2002–03	2003–04	2004-05
AAO papers	68	84	62	75	122
AAT papers	68	100	91	112	112
UKST papers	39	40	25	30	25
AAT papers/program	0.7	1.2	1.2	1.6	1.8

The figures show that the number of AAT publications has been steadily increasing, attaining an all-time high in 2003–04 and 2004-05 primarily as a result of the 2dF redshift surveys and their public data releases. A similar increase in UKST papers is anticipated after the completion and release of the 6dF Galaxy Survey and the first RAVE data release (both in 2006). The move to large time allocations in general and survey-type programmes in particular is also credited for the increasing trend in papers per programme on the AAT, from the traditional 0.7–0.9 to another all-time high of 1.8 in 2004-05.

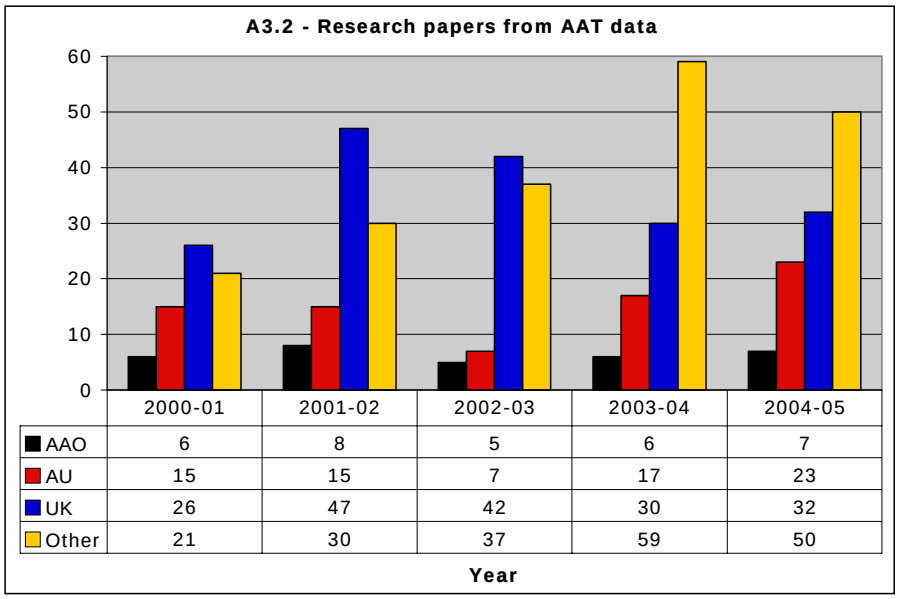


Figure A3.2 shows the numbers of research papers based on AAT data with first authors from the AAO, Australia, the UK and other countries. After a lull in 2002-03, the number of Australian papers has increased to a high of 23 in 2004-05. The number of UK papers peaked at 47 in 2001-02 and then dropped back to 32 last year. The number of papers by AAO staff has been steady, but the number with first authors from other countries has been increasing strongly.

The most recent analysis of citation data for all the major optical/infrared telescopes in the world is given by Trimble, Zaich & Bosler in 2005 (*Productivity and Impact of Optical Telescopes*, *PASP*, 117, 111). They compare both total citations and high-impact papers in evaluating the performance of telescopes operating in 2001. By both measures the AAT performs extremely well (Table 4 of Trimble et al., reproduced as Table A3.3).

A3.3 - Papers and citations by telescope (Trimble et al. 2005, Table 4)

TABLE 4
PAPERS AND CITATIONS BY TELESCOPE

Telescope	Citations	Papers	C/P
Hubble ST	4747	346.3	13.71
Mauna Kea:			
Keck	2180	104.5	20.86
Subaru	197	18.7	10.53
CFHT	697	49.2	14.17
Univ. Hawaii 2.2 m	88	18.7	4.71
UKIRT	586	43.7	13.41
IRTF	285	23.8	11.97
JCMT	702	49.5	14.18
ESO:			
VLT	864	69.8	12.38
3.6 m	324	41.2	7.86
NTT	399	34.5	11.57
2.2 m	282	26.7	10.56
Other	584	85.8	6.81
Mount Hopkins:			
MMT	190	17.0	11.81
Whipple 1.5 m	93	9.0	10.33
Other	192	9.8	19.59
SAO Russia:			
6 m	154	37.0	4.16
Other	0	1.7	0
Palomar Mountain:			
5 m	299	18.2	16.43
Other	24	3.3	7.27
Canary Islands:			
WHT	686	44.0	15.59
TN Galileo	112	11.0	10.18
NOT	135	29.3	4.61
INT	204	23.0	8.87
Other	220	23.3	9.44
Cerro Tololo:			
Blanco 4 m	348	27.3	12.75
Other	307	43.7	7.03
Kitt Peak:			
Mayall 4 m	466	27.5	16.97
WIYN	120	14.0	8.57
MDM	182	14.7	12.38
Other	292	24.0	12.17
Australia:			
AAT	1253	45.0	27.84
MSSO 2.3 m	15	7.5	2.0
Other	59	7.5	7.87
Calar Alto:			
3.5 m	158	16.7	9.46
2.2 m	244	18.3	13.33
Other	58	6.0	9.67
Apache Point ARC	65	10.0	6.50
Mount Hamilton:			
3 m	383	18.3	20.93
Other	48	6.7	7.16
McDonald:			
2.7 m	202	17.3	11.68
2.1 m	122	11.7	10.43
Other	17	2.0	8.5
Crimea:			
2.6 m	15	7.0	2.14
Other	38	20.0	1.90
Las Campanas:			
2.5 m	248	17.2	14.42
Other	200	17.0	11.76
WIRO	50	1.5	33.33
Bappu 2.3 m	6	2.0	3.0
Steward Observatory:			
2.3 m	121	9.3	13.01
Other	4	1.5	2.67
Xingliong 2.2 m	40	10.7	3.74
Pic du Midi:			
2.2 m	11	4.5	2.44
Other	1	2.0	0.5
Catanea 2.2 m	30	11.0	2.73
Casleo 2.15 m	74	20.5	3.61
San Pedro Mártir:			
2.1 m	46	10.0	4.60
Other	6	2.1	2.86
Eastern 2 m class[a]:			
Total	79	29.1	2.68
Obs. Haute Provence:			
1.93 m	123	14.0	8.79
Other	28	8.0	3.50
South Africa:			
1.9 m	84	14.0	6.00
Other	92	18.0	5.11
David Dunlop Obs. 1.9 m	28	4.8	5.83
NOAO Japan:			
1.88 m	58	7.3	7.95
Other	19	5.3	3.58
Dominion Astrophysical Obs.:			
1.85 m	7	2.4	2.92
Other	0	0.9	0
Telescopes ramping up total[b]	107	7.7	13.90
Special Purpose Facilities:			
SDSS	1252	31.3	40.00
2MASS	558	27.5	20.29
DENIS	84	9.5	8.84
Schmidt surveys	501	48.9	10.33
Microlens searches	253	23.0	11.00
Automatic photometric telescopes, refractors, meridian circles total	104	22.5	4.62
Interferometers	139	13.0	10.49
1.6–1.83 m	108	24.0	4.50
1.5–1.6 m	84	24.7	3.40
1.0–1.49 m	208	48.5	4.29
<1.0 m	537	107	5.02

TABLE 4 *Continued*

[a] Bulgaria, Azerbaijan, Ondrejov, Terskol, Tautenberg, Maidanak.
[b] Gemini, HET, Magellan.

Trimble et al. compare the total citation rates for optical/infrared telescopes, and show that in 2001 the AAT had the third-highest total number of citations (behind HST and Keck, although at that time the VLT was still ramping up and Gemini was too new to include in the analysis) and also the third-highest number of citations per paper (behind SDSS and WIRO). The AAT also had nearly twice as many citations as any other 4-metre telescope.

Of the 16 most-cited papers published in 2001 (those with more than 100 citations by the time of Trimble et al.'s analysis – see their Table 2), four are based on data from the AAT; all four of these high-impact papers are from the 2dF Galaxy Redshift Survey. Another measure of the AAO's impact is that 17 of the 300 most-cited papers produced by the international astronomical community over the three years from 2002 to 2004 (the top 0.5% of all papers published in this period) were substantially based on AAT data.

Trimble et al. also compared the number of papers from optical/infrared telescopes in 2001 with the results of a similar survey a decade earlier. Table 1 of Trimble et al. shows that the total number of papers produced by most 4-metre optical telescopes has decreased by 10-20% between 1991 and 2001. However in 2001 the AAT was still, as it was in 1991, the most productive 4-metre telescope in the world.

An updated analysis including telescopes operating at other wavelengths was presented by Trimble et al. at the January 2006 American Astronomical Society meeting and reported in *Nature (*439, 250-251; reproduced as Table A3.4). The impact factor used is citations per paper, by which measure the AAT ranked fourth among all observatories in 2001.

A3.4 – Selected astronomical facilities and impact factors

	Papers	Citations	Citations per paper
Maxima balloon experiment	5.6	456	81.43
Sloan Digital Sky Survey	31.3	1,252	40.00
Chandra	175.8	6092	34.60
Anglo-Australian Telescope	45	1,253	27.84
Keck	104.5	2,180	20.86
Very Large Array	181.4	3,003	16.55
William Herschel Telescope	44	686	15.59
Hubble Space Telescope	346.3	4,747	13.71
Very Large Telescope	69.8	864	12.38

Source: Virginia Trimble, Paul Zaich, Tammy Bosler

The productivity and impact of Australian astronomical institutions was assessed in the study *A Bibliometric Analysis of Astronomical Sciences Publications* by Biglia & Butler, commissioned as part of the *Australian Astronomy Decadal Plan 2006-2015* (see Annex C1 at http://www.atnf.csiro.au/nca/DP_Volume2.html). Comparing papers produced in the 5-year period 1998-2002, this study found that the AAO was ranked 4th in total number of papers, 3rd in the number of papers in the top 1% of most-cited papers, and 2nd in the number of papers in the top 5% of most-cited papers – see Biglia & Butler, Table 3 (reproduced below as Table A3.5). It is important to note that these rankings are based on absolute numbers of papers, not numbers relative to the number of people at each institution.

A3.5 – Selected astronomical facilities and impact factors

	Total Pubs	Pubs in top 1%		Pubs in top 5%	
	No.	No.	%	No.	%
The Australian National University	607	13	2.1	51	8.4
Anglo-Australian Observatory	285	2	0.7	24	8.4
University of New South Wales	253	7	2.8	20	7.9
Australia Telescope National Facility	386	2	0.5	16	4.1
University of Tasmania	112			3	2.7
University of Melbourne	109			2	1.8
University of Sydney	392			7	1.8
Monash University	84	1	1.2	7	8.3
University of Adelaide	77	1	1.3	4	5.2
Australian Defence Force Academy	77			3	3.9
Swinburne University	82	1	1.2	2	2.4

Another study carried out in 2005 for the *Decadal Plan* was the *Australian Astronomy Publication and Facilities Survey,* which reviewed the productivity and impact of all facilities, both national and international, available to Australian astronomers across all wavebands (see Annex W1 at http://www.atnf.csiro.au/nca/DP_Volume2.html). As measured by both publication numbers and citation rates for papers published in the period 1996-2004, the study concluded that the facilities provided by the AAO and ATNF are the most influential within the Australian community, with important contributions by the ANU optical facilities and the theoretical community. The AAT was ranked first for impact amongst all facilities used by Australian astronomers.

APPENDIX 4

INSTRUMENTATION PROGRAMME

The AAO's astronomical instrumentation programme encompasses both technology research and development and instrument design and construction. The programme currently involves 27 staff members: 22 in the Instrumentation group and five in the Instrument Science group. The AAO builds instruments for both its own telescopes (generally funded internally) and for other telescopes in Australia and around the world (generally funded externally). It collaborates with a variety of Australian and international institutions on many of its instrumentation projects. Table A4.1 (overleaf) provides an overview of the AAO's instrumentation and technology programme, listing recent major internal and external projects, other recent projects and current R&D technology projects.

The major instruments completed for the AAO's telescope in the past five years are:

- WFI – the Wide-Field Imager is a CCD mosaic imager built in collaboration with RSAA and the University of Melbourne; WFI is used on both RSAA's 40-inch telescope and the AAT.
- 6dF – the 6-degree Field fibre spectrograph was built by AAO to replace FLAIR on the UKST; 6dF has been used for the 6dF Galaxy Survey and the RAVE stellar survey; it was the prototype for OzPoz.
- IRIS2 – this InfraRed Imaging Spectrograph is the successor to IRIS1 and is one of the most-used instruments on the AAT; it won an Australian Engineering Excellence Award in 2002.
- AAOmega – this innovative dual-beam spectrograph replaces the 2dF spectrographs and provides both wide-field multi-object spectroscopy and, in combination with SPIRAL, integral field spectroscopy.

With the exception of WFI, these instruments have been funded entirely from the AAO's recurrent funding, and represent an investment of over $10 million in providing cutting-edge instrumentation for Australian and British astronomers.

The major instruments that the AAO has undertaken in the last five years for other telescopes around the world are:

- OzPoz – the fibre positioner for the FLAMES facility on the European Southern Observatory's Very Large Telescope in Chile; OzPoz represents the culmination of the fibre positioner technology developed at the AAO and utilized in the 2dF and 6dF instruments.
- Echidna – the fibre positioner for the Faint Multi-Object Spectrograph (FMOS) on the Japanese Subaru telescope; this instrument embodies the eponymous 'spine' technology that is also to be used in WFMOS.
- DAZLE – the Dark Ages high-Z Lyman Explorer is a highly specialised instrument that was designed by the AAO and is currently being built in Cambridge for ESO's Very Large Telescope.
- WFMOS – the Wide-Field Multi-Object Spectrograph is one of the 'Aspen' generation of instruments proposed by the Gemini partnership; it will actually be used on the Japanese Subaru telescope as part of an arrangement between the two observatories to share instrument costs and swap time; the AAO is currently performing a concept study, with a decision on whether to build the instrument to follow in mid-2007.

A4.1 - Overview of AAO instrumentation and technology program

	Instrument	Description	Telescope	Funding	Completion
Recent major internal projects	WFI	Wide Field Imager	AAT/40"	AAO/ANU/U.Melb.	2001
	6dF	Six-degree Field fibre spectrograph	UKST	AAO	2001
	IRIS2	InfraRed Imager and Spectrograph	AAT	AAO	2002
	AAOmega	Wide-field dual-beam fibre spectrograph	AAT	AAO	2006
Recent major external projects	OzPoz/FLAMES	Fibre positioner for FLAMES spectrograph	VLT	ESO	2003
	Echidna/FMOS	Fibre positioner for FMOS spectrograph	Subaru	Subaru	2006
	DAZLE	Dark Ages High Redshift Lyman Explorer	VLT	PPARC/IoA	2006
	WFMOS	Wide Field Multi-Object Spectrograph	Subaru	Gemini/Subaru	~2011
Other recent internal projects	DomeAir	AAT Dome Air Conditioning	AAT	AAO	2005
	ODC	Optical Detector Controllers	AAT	AAO	2005
	ICI	Instrument Control & Integration	AAT	AAO	2006
	TCS	Telescope Control System	AAT	AAO	2007
Other recent external projects	SuperAAPS	Upgrade to UCLES spectrograph	AAT	PPARC	2006
	APTcamera	Mosaic CCD camera	APT	UNSW	2006
	SONGspec	Stellar Oscillation Network Group study	SONG	Denmark	2006
	KWFS	Korean Wide-Field Spectrograph study	KLT	KASI	2006
Current R&D projects	Astrophotonics	New fibre technologies	any	AAO/PPARC	on-going
	Sky suppression	Aperiodic Fibre Bragg Gratings	any	AAO/ESO/PPARC	on-going
	Starbugs	Autonomous focal plane devices	any	AAO/EU	on-going

These major external instruments have brought more than $10 million in contracts to the AAO and provided additional opportunities for Australian astronomers to collaborate with international astronomers in using the world's largest telescopes and most powerful instruments. The AAO currently obtains about 20% of its annual income from external instrumentation contracts.

Table A4.1 also lists other, smaller-scale internal and external instrumentation projects. The smaller internal projects are mainly subsystems and infrastructure upgrades and enhancements for the AAT, and include air-conditioning the dome to improve the seeing on the AAT, providing new and more capable controllers for both optical and infrared detectors, and upgrading the control systems for some of the older instruments and the telescope itself.

The smaller externally-funded projects include an upgrade to the AAT's UCLES spectrograph for the Anglo-Australian Planet Search (AAPS), a larger and more efficient CCD camera for the University of New South Wales' Automated Patrol Telescope (APT) at Siding Spring, a spectrograph design study for the Solar Oscillation Network Group (SONG), and a potential concept study for a WFMOS-like spectrograph for the proposed Korean Large Telescope (KLT). These projects generally provide new or upgraded facilities for the AAO (e.g. SuperAAPS) or for other Australian institutions (e.g. the APT camera for the University of New South Wales and SONG for the University of Sydney); alternatively they provide opportunities to develop major new external projects (e.g. for Korea's Large Telescope).

The technology R&D projects provide the new technologies on which AAO's international reputation for instrumentation is based, and the specific strengths and expertise that allow the AAO to win instrumentation contracts in a highly competitive international environment. The main current strands of technology development are:

- Astrophotonics – encompasses the development of new fibre-optic technologies and explores their applications to astronomical instrumentation; this work has been done in collaboration with the University of Durham.
- Sky-suppression fibres – the AAO has pioneered the development of aperiodic fibre Bragg gratings and their application to suppressing the OH sky-lines in the near-infrared; this work has been done in collaboration with Redfern Optical Components in Australia and the University of Bath in the UK.
- Starbugs – an outgrowth of the AAO's Echidna spines technology, starbugs are autonomous focal-plane devices that promise to provide a uniquely versatile solution to

some of the instrumentation problems posed by the scale of large (and extremely large) telescopes.

The AAO's work on these and other R&D projects represents an investment in the future of the instrumentation programme.

For further information see http://www.aao.gov.au/astro/instrum.html

APPENDIX 5

RESEARCH STUDENTS

The AAO is not a PhD-awarding institution, but it makes two types of contributions to student research: (i) providing data for a thesis and (ii) providing co-supervision for students at universities.

(i) To quantify the contribution the AAO makes through providing thesis data, we estimated the number of PhDs generated using the AAT from the students listed explicitly on successful AAT proposals. Over the five years spanned by semesters 01A-05B, there were 46 students who used the AAT to obtain data for their PhD research: 19 from Australia, 23 from the UK and four from other countries.

(ii) AAO staff have co-supervised 24 PhD students during the past five years, of whom 22 have been Australian. PhDs have been awarded to 11 of these students, while the other 13 are still in progress.

Table A5.1: Australian research students and their institutions using the AAT 2001-2005

	PhD data	PhD co-supervision
Australian National University	9	8
University of Sydney	2	6
Macquarie University	1	6
Swinburne University	2	1
University of Southern Queensland	2	1
Monash University	1	0
Melbourne University	1	0
University of New South Wales	1	0
TOTAL	**19**	**22**

Combining both categories, the AAO staff and facilities have contributed to training a total of 31 postgraduate students over the five years 2001-05. AAO staff have also co-supervised the research projects of at least eight undergraduate Honours students.

In addition, the AAO has for many years hosted senior undergraduates from Australian and UK universities as Summer Scholars; over the past five years there have been 17 Australian and 17 UK Summer Scholars. Most go on to do PhDs in astronomy and about half carry on to postdoctoral research positions. A significant number of established Australian astronomers today went through the AAO studentship programme.