Gemini & SKA Major National Research Facility
2005 Review Committee Report

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Executive Summary

This MNRF has provided critically-needed development funds for the major priorities in Australian astronomy, the Gemini 8-m telescope and the Square Kilometre Array (SKA). The Review Committee was very impressed by the progress in the many MNRF-supported programs. While there have been some delays, the committee noted that the overall objectives appear to be within reach as corrective actions are implemented. A number of specific comments and suggestions on each of the major areas of the MNRF are detailed in this report. In particular, the committee flagged the importance of further building partnerships for access to Gemini/8-m telescopes and Extremely Large Telescopes (ELT), and the need for strong focus on the two key elements of Australia's bid for a major role in the SKA, the site proposal and timely completion of the New Technology Demonstrator (NTD). Overall, it is clear to the committee that the MNRF program is significantly advancing astronomy in Australia by paving the way for the major projects of the future.

Introduction

A review of the Gemini and SKA Major National Research Facility (MNRF) took place over the period 6-9 June 2005. The Department of Education, Science and Training (DEST) invited three reviewers from overseas: Dr. Tony Beasley (ALMA Project Manager, Santiago, Chile), Prof. Garth Illingworth (University of California, Santa Cruz), and Dr. Peter Shaver (European Southern Observatory, Munich).

The review committee was asked to:

- Appraise the performance of the facility, with a focus on the scientific aspects and overall relevance
- Identify the opportunities that could further enhance the performance of the facility, and those areas of concern that may threaten the achievement of the facility objectives
- Identify those areas of scientific strength which should be maintained and developed by the facility, and any weaknesses and gaps that the facility should address.

Background materials provided included the MNRF Business Plan, the three available Annual Reports, the revised NTD Project Plan, and the report on the November 2004 review of the revised NTD Project Plan. Additional documents that were provided to the review committee included the SKA and ELT roadmaps, and the draft executive summary of the Australian Astronomy's Decadal Plan for 2006-2015. During the period 6-9 June 2005 visits were arranged to the various facilities of the MNRF (RSAA, Mologlo, AAO and ATNF), an open Symposium was held on the MNRF, interviews of representatives of all the facilities took place, and a meeting was held with the Australian Astronomy Board of Management (AABoM) to discuss the preliminary conclusions of the review committee.

This report is structured to first deal with broad issues for the MNRF Project Office and AABoM, then focuses on the two major components of the program, Gemini/ELT and the SKA, in that order. Individual MNRF programs are listed separately under these two major components.

AABoM/MNRF Project Office

As this MNRF concerns the two major priorities of Australian astronomy – Gemini and SKA – it is clearly of great importance to the wide astronomy community. However the committee was concerned about the extent of community involvement, which was not at all clear in the documentation. We were aware that a decadal review is being prepared, and of course this should go a long way in this direction. The advisory committees of AABoM also provide significant community input. Nevertheless we feel that there could be still more representation in the MNRF decision-making process from the whole astronomical community, especially from the universities. The AABoM currently includes representatives of the major facilities. While valuable for efficient input from the major players, such a committee structure could be criticized by the community as lacking independence. One step towards alleviating this concern would be to add one additional member to the AABoM, as a representative of the entire university community.

The committee also felt that the roles and responsibilities of the advisory committees and AABoM need clarification – the MNRF-Facility interfaces seemed somewhat unclear (e.g., the process for authorizing changes to MNRF projects and budgets could be described and made available to the community).

Underlying many of the subprograms described during the review are links to external events that are beyond the scope of the MNRF – other groups or countries funding ELT development, an international SKA timeline for decisions, and ongoing redefinition of the technical requirements for the SKA. It is difficult to plan sensibly when the ground is moving like this, but in the absence of a clear controlled definition of the MNRF subprograms goals, and management of the technical requirements and flowdown to the hardware descriptions, there is the potential for significant inefficiencies.

A stronger Project Office would improve coordination and communication in the MNRF. Managing a diverse collection of projects is a difficult challenge, and better communication may lead to more efficient sharing of resources and avoiding duplication of research efforts (a risk arising from separate institutions working on related tasks, e.g., digital beamforming). Monthly teleconferences are an efficient way of enhancing both coordination and communication, and quarterly meetings may also be advisable. A larger fraction of the time of both the Director and Executive Officer devoted to the MNRF will be required. Hiring an Executive Assistant would certainly strengthen the Project Office considerably. The review committee also felt that the MNRF Project Office could benefit from the involvement of more project management on a fractional basis to complement the Director and the financial oversight by the Executive Officer. This addition would be beneficial to both the Project Office and the several disparate groups involved in the MNRF.

Efficient standards for project reporting to the Project Office and AABoM are advisable. Several groups complained about their onerous and varied reporting requirements, both from the MNRF and from several other bodies. A stronger Project Office could alleviate the burden by designing efficient and effective standards for the project reports, and providing help and guidance for some of the smaller MNRF projects.

The committee felt that the Project Office and AABoM should continuously consider opportunities to identify and shift funds around to maximize the return of the MNRF. Opportunities should be considered to target programs that could benefit the MNRF from incremental funding (e.g., RSAA NIFS/GSAOI instruments). The level of matching funds for the MNRF was impressive. While further matching funds would not lead to increased MNRF funding at this time, it would be good to identify those “additional funds” that the community has found from other sources (particularly international sources) that demonstrate the vitality of the program in the core areas supported by the MNRF (e.g., RSAA Gemini funds and additional NTD funds).

MNRF Gemini/8-m Program

Large telescopes in the optical-IR remain a central tool for astronomers worldwide in their quest to explore and answer many of the key scientific questions of the day. Australian astronomers have impacted the field for a long time, beyond what their numbers would indicate, by their deft and imaginative utilization of astronomy facilities for forefront scientific initiatives and their focused efforts to leverage their expertise into access and collaborative ventures.

The current frontier for large optical-IR telescopes lies around 8-m, with Extremely Large Telescopes (ELT) of size 20-30m and beyond being the next milestone for both the USA and Europe in the coming decade. The Australian astronomy community and DEST are to be commended for their recognition of the need for significant involvement in such facilities.

The MNRF support for 8-m projects through Gemini is key to Australia's involvement in the current generation of large optical-IR telescopes. It has been reassuring to see that, in all respects (demand for observing time, completion rates of programs, etc.) Australia's utilization of Gemini has significantly increased over the first few years of this MNRF. The challenges of increasing the Gemini share have led to exploration of other approaches to enhance the access to 8-m class facilities. In addition, the first steps have been taken to support positioning Australia for possible involvement in an ELT project. The MNRF review committee views the support by the Government of the Astronomy MNRF 8-m and ELT program as a far-sighted effort that brings great vitality to Australia's forefront astronomy program, and further enhances Australia's standing in the scientific and technical arena worldwide.

Gemini/8-m Time

The review committee felt that the MNRF effort to buy Chile's share of the Gemini 8-m project to increase the Australian component of this long-term facility was a very effective use of funding. A somewhat unexpected response from the other partners led to only a small fraction of the Chilean time being recoverable for Australia. Part of the Australian response to this situation has been to negotiate access for observing through "buying time" from other Gemini partners. While this certainly provides scientific opportunities for Australian astronomers now and in the near future, especially if it is a cost effective approach in the near term, the MNRF review committee is concerned, however, that this does not position Australia to be a long-term player with increased access.

The MNRF review committee felt that it was better to "buy share", rather than to "buy time". Building partnerships for the long term has many benefits for the astronomy research community beyond access (e.g., student involvement, long term strengthening of science programs, development of strong and visible research groups, solidifying a strong technical instrument development base through continuity). The options for increased share in Gemini might be appear to be small, but they should not be considered to be zero – an aggressive proactive approach to buying share may well be rewarded given the current fiscal challenges for many nations, even if initial overtures are rejected.

An alternative approach mentioned to the committee is to enter into discussions with the Magellan project. While slightly smaller at 6.5 m, these telescopes are widely considered to be "8-m class" facilities because of their excellent site and instruments. The end result of these efforts might be to have the increased access to 8-m class telescopes through both Gemini and another facility. The MNRF Review Committee felt that such an approach is a good one, assuming that the access is through partnerships. Presumably the implicit commitment of the government to support an increased share of Gemini (as a result of the key commitment of this MNRF to buy a larger share - i.e. a larger partnership role) could be broadened to encompass an increased share in Gemini plus another 8-m class facility - provided, of course, that the combined operations commitments were essentially cost-neutral (i.e. the same whether it was solely increased Gemini share or current Gemini plus another 8-m class partner).

Extremely Large Telescopes

The committee would like to commend the DEST, AABoM and the MNRF project for their willingness to make a mid-course correction to the program and support the activities of an ELT Project Scientist. The timing is right for the Australian community to be seen as a potential partner in such efforts, since several groups are in the early planning stages for such facilities.

There is a very strong commitment to ELTs in the USA and Europe, with two major projects undergoing early development in the US (Giant Magellan Telescope GMT and Thirty Meter Telescope TMT), and one in Europe (Overwhelmingly Large Telescope OWL). While it is unclear which project(s) will come to fruition, there is extremely strong support for a national ELT project in the US to be completed in the next decade. This project, the 30-m Giant Segmented Mirror Telescope (GSMT), was ranked number one in the current (2000) US Decadal Survey. One of the two current projects, GMT or TMT, will be selected to go forward. A similar European initiative for an ELT is also a high priority, and may well develop on a similar timescale.

The committee notes that the focus of the current Australian ELT discussions on the GMT project appears to be a wise approach, given the nature of that partnership (the partners have a share and contribution that may match well with a possible future Australian contribution). The committee also noted that progress on an ELT may be enhanced by decoupling the ELT planning and discussions from the interest in an Antarctic site (at least until the quality and feasibility of the site have been rigorously assessed over an adequate time frame), given the timescale for the first generation of ELT projects with whom Australia would be partnering and the challenges of implementing large facilities at Dome C.

In summary, the review committee strongly supports exploiting opportunities for ELT involvement, given the potential scientific capabilities of such a facility. Since significant effort is being undertaken in both the US and Europe on ELT development, the MNRF support of ELT activities at this time can help position Australia as opportunities develop. The funding of an ELT Project Scientist is a realistic and cost-effective approach to exploring opportunities for potential ELT partnerships.

Gemini Instruments

RSAA: The MNRF Review Committee visited the RSAA and discussed with the Principal Investigator (PI) the two major cryogenic instruments being fabricated for Gemini (Near-infrared Integral Field Spectrograph NIFS and Gemini South Adaptive Optics Imager GSAOI). Subsequent presentations in the following days gave more background and insight into the issues surrounding the completion of these very important but very challenging cryogenic instruments. The committee was surprised to hear that the non-government funding from the Gemini project was not being included as a matching contribution to the MNRF. The committee felt that such large contributions of foreign funding should be acknowledged enthusiastically as a major coup for Australian astronomy, and recognition of the strength of the RSAA instrument program, by inclusion as “additional funding".

The current challenges of meeting the delivery schedules to Gemini of both NIFS and GSAOI were a concern for the committee. These are a very visible aspect of the Australian Gemini program and delivery delays could potentially impact the AAO's effort on the Gemini Wide Field Multi-Object Spectrograph (WFMOS). The committee felt that MNRF assistance with funding the RSAA Gemini instruments might be a good utilization of some of the available MNRF funds. Some increased access for the Australian astronomy community to Gemini could potentially accrue from this.

AAO: The committee also visited the AAO and was very impressed with their development of forefront technologies, some of which have led to patents. The focal plane fibre-positioning piezoelectric technology and fibre-based OH suppression innovations particularly impressed the committee. The AAO group clearly has substantial strengths and has the potential to be a major player in both near-term 8-m instrumentation and future ELT efforts. The committee felt very positive about the AAO plans to be a

major competitor for both the WFMOS concept study and for the full instrument development. The committee recommends that AABoM and the MNRF management consider using some of the available MNRF funds to enhance the competitiveness of the AAO for the full WFMOS instrument proposal that follows the concept study.

The Review Committee commends the AAO for anticipating WFMOS construction with their Project Management initiative, e.g., the plans to introduce an Earned Value Management System (EVMS). This forward-thinking approach to the need for a sophisticated Project Management system for a ~US$60M instrument is highly encouraging.

SKA & Related Activities

The International Square Kilometre Array (SKA) project is a worldwide effort to define and construct a radio telescope two orders of magnitude more sensitive and flexible than existing arrays. The SKA will be a counterpart of the other major ground-based facilities of the world, the ELT(s) and ALMA. Australia is one of the founding members of the SKA, and over the past decade has figured prominently in the development of the project. If the SKA is located in Australia, with significant Australian financial, technical and scientific participation, it will be a major coup for Australia, placing it at the forefront of world astronomical research for decades to come.

The SKA project is currently approaching two significant deadlines – a site selection decision due in 2006, and a technology downselect decision (either lowering the number of options under consideration, or actually choosing the final design) in 2009. The MNRF grant under review is providing funding for Australian scientists to compete strongly in these key decisions, supporting a broad mix of research efforts including exploration of novel antenna/feed technologies, digital beamforming and wideband correlator concepts, investigating imaging and data transfer issues associated with the design concepts via supercomputer simulations, and characterization of what is (most likely) the preferred site for the SKA. In many cases, these research efforts are also upgrading existing instruments to provide unique scientific capabilities to the Australian astronomical community.

Of this diverse set of important activities, the committee noted that the upcoming SKA site selection and the technology downselect decisions made the Mileura Station proposal and the NTD extremely important activities for the future of SKA in Australia, and thus of vital importance for the MNRF program.

During the review the committee was presented both the scientific and technical motivations for the various subprograms, and detailed summaries of subprogram management status. The definition of some of the subprograms has shifted based on research findings during the course of the MNRF, and the committee was encouraged to note that appropriate project change control mechanisms (including extensive community consultation) appear to have been implemented by the AABoM.

AT Compact Array Broadband Backend

Significant progress has been made on developing a 2 GHz broadband correlator to be implemented on the AT Compact Array. The imminent arrival of the DFB cards represents a significant milestone towards the completion of this system which will both explore new digital technologies required for the SKA and provide an important new scientific capability for the existing telescope. Although most of the technical risk appears to be mitigated at this point, the schedule presented for CABB completion was highly success-oriented. We note that the CABB directly involves key technical staff from ATNF and therefore additional delays to CABB could impact MNRF follow-on activities (most notably xNTD). The committee urges the MNRF and ATNF Project Offices to carefully monitor CABB development and reallocate resources as needed to keep this important development on schedule.

The committee was told that with this recent work the in-house capabilities of ATNF for PCB layout had eventually been exceeded, and that a contract with an offshore firm had been required. Based on a very brief discussion this situation suggested there may be opportunities to form collaborations with Australian industry to develop such local capabilities which could be extended beyond the CABB requirements, and we recommend that the MNRF project office explore such opportunities whenever possible.

Monolithic Microwave Integrated Circuits

Significant progress has been made in developing Microwave/Millimetre-wave Integrated Circuits (MMICs). InP HEMT MMICs are expected to find use in the 3 mm upgrade of Mopra and the 7 mm systems planned for the Compact Array. Some of the original goals of the MMIC development (such as supplying components for CABB and SKA demonstrators, e.g., NTD) have been found unnecessary due to utilization of commercially-available devices and shifts in strategic direction, and funds have been reallocated by AABoM. The committee suggests that projects not directly coupled to the MNRF (e.g the new 7mm systems) should be carefully monitored to avoid resource conflicts.

SKA Molonglo Prototype

This subprogram will upgrade the Molonglo telescope to be a world-class spectral line instrument, at the same time developing technologies of relevance to the SKA including cylindrical collecting areas, digital beamforming and line feeds. These efforts are building upon the unique investment made in Molonglo over many decades. Cylindrical collecting areas are considered to be cost-effective, therefore the committee notes that the Molonglo upgrade must be pursued <u>both</u> as providing a potential SKA technology and also producing a scientifically-interesting new instrument for southern hemisphere radio astronomy (the SKA relevance should be stressed more than it has been in the past).

The SKAMP subprogram is broken into three linked and ambitious stages, and the committee is concerned that the resources allocated to these efforts may be insufficient to guarantee completion in a timely fashion. As we mention above, the SKAMP work must take place within an absolute schedule determined by MNRF funding and SKA decision making. The collaboration between the ATNF Project Office and Molonglo to direct project management resources to SKAMP is an excellent step. The progress presented to the committee during the review was extremely promising, and if appropriately resourced and managed all three SKAMP developments are capable of meeting their goals.

The committee also notes that the SKAMP subprogram has another extremely important deliverable to the MNRF and society in general – producing scientifically and technically-literate students who are well-grounded in digital electronics and radio astronomy. The hands-on training provided by this kind of development program is vital to ensuring Australia's continued major role in these fields.

SKA Site

Preparation of the document proposing the Mileura Station region in Western Australia as the SKA site appears to be well underway, and information gathering and RFI testing are progressing. This proposal is of absolutely vital importance for Australia's role in the SKA, and the committee recommends that the MNRF Project Office closely monitor its production and resource the efforts appropriately. Mitigation of all risks associated with the proposal production (e.g., unexpected staffing absences) should be pursued.

SKA Supercomputer Simulations

Excellent progress has been made in the SKA supercomputer simulation and baseband processing area, and the committee commends the Swinburne team for their efforts and remarkable success. This facility is simultaneously providing key information to the SKA project (including the MAPS interface, SKA costing models and RFI analysis) and developing new VLBI and pulsar technologies for the southern

hemisphere (pulsar processing, software correlator, disk-based recording and real-time fringe checking). Swinburne is also making a key contribution by producing highly trained students.

New Technology Demonstrator

The NTD is a crucial step for ensuring Australia's strong contribution to the SKA project, and, together with the SKA site, should be the highest priority within the SKA sections of the MNRF grant. Australia has now selected a technology it believes will meet the demanding (and evolving) SKA scientific and technical requirements (focal plane arrays on parabolic dishes), and successful deployment of the NTD will position Australian researchers to take a leadership role in SKA development. At this point it is clear that several significant technical issues remain which must be addressed as soon as possible.

Two concerns arose during careful review of the project plan and management strategies for the NTD:

- *Project management issues:* management of the NTD subprogram is overseen by the MNRF Project Office and the ATNF Project Office. Formal project management approaches are visible - however, certain key elements (in particular, requirements management and risk identification and mitigation) appeared to be missing in the materials presented. It was noted that the PDR and CDR for NTD have been delayed, yet at this point the completion date remains unchanged – this is unrealistic. Given the R&D nature of the NTD effort, and the importance of a timely and successful completion of the program, the committee strongly recommends that the MNRF Project Office routinely reviews NTD project management performance.

- *The impact of other (non-MNRF) programs to the NTD schedule:* The NTD is an ATNF deliverable, and during the review the committee was informed about several ongoing ATNF programs which could compete for resources (primarily key staff) with NTD development. Funding for an extended NTD (xNTD) has recently been acquired, and it is understood that the staff presenting the NTD materials would also take a major role in xNTD. As noted in an independent review in November 2004, the schedule for xNTD is somewhat undefined, and the committee is concerned that inappropriate focus on the xNTD before the more fundamental technical issues are found and resolved on the NTD could jeopardize Australia's chances to compete strongly in the SKA technology downselect. The review committee was encouraged to hear that the AABoM, MNRF and ANTF managements are aware of the situation and are moving to guarantee the NTD deliverables.

The Future

The review committee was pleased to hear that the present MNRF is likely to be followed by an even larger initiative: the National Collaborative Research Infrastructure Strategy (NCRIS). It is understood that NCRIS will have an overall budget that is several times larger, and yet will extend down to smaller projects. There is then the question as to whether the astronomy NCRIS should provide an envelope for a broad range of astronomy projects, or whether it should focus exclusively on ELT and SKA. In either case, the review committee feels that there should be a stronger, more directed focus in both the ELT and SKA programs (both of which should include all relevant efforts in Australia). It is important that the efforts towards each of these two facilities be very tightly focussed and managed, and given the highest possible priority, in order to assure that they proceed directly and efficiently to the ultimate goals.

Acknowledgements

The review committee is grateful to the many who contributed to and enhanced the review process. The format of the review, with site visits, a Symposium, a detailed project-by-project review, and a high-level de-briefing session, was really excellent. Particular thanks are due to MNRF Director Lister Staveley-Smith, who expertly organized the entire process from end to end. The Chair of AABoM Martin Cole and the MNRF Executive Officer Mark McAuley spent considerable time with the review committee and gave us much appreciated insight and background. The review committee also appreciated the many discussions we had with the DEST representatives on the review, David Wilson and Joslin Moore, and the thoughtful feedback they provided us on the Government's role in establishing and supporting the MNRF program.

Acronyms

AABoM	Australian Astronomy Board of Management
AAO	Anglo-Australian Observatory
ALMA	Atacama Large Millimeter Array
ATNF	Australia Telescope National Facility
CABB	Compact Array Broadband Backend
CDR	Critical Design Review
DEST	Department of Education, Science and Training
DFB	Digital Filter Bank
ELT	Extremely Large Telescope
EVMS	Earned Value Management System
GMT	Giant Magellan Telescope
GSMT	Giant Segmented Mirror Telescope
GSAOI	Gemini South Adaptive Optics Imager
MAPS	MIT Array Performance Software
MMIC	Monolithic Microwave Integrated Circuit
MNRF	Major National Research Facility
NCRIS	National Collaborative Research Infrastructure Strategy
NIFS	Near-infrared Integral Field Spectrograph
NTD	New Technology Demonstrator
OWL	Overwhelmingly Large Telescope
PCB	Printed Circuit Board
PDR	Preliminary Design Review
RFI	Radio-Frequency Interference
RSAA	Research School of Astronomy and Astrophysics
SKA	Square Kilometre Array
SKAMP	SKA Molonglo Prototype
SKASS	SKA Supercomputer Simulations
TMT	Thirty-Meter Telescope
VLBI	Very Long Baseline Interferometry
WFMOS	Gemini Wide Field Multi-Object Spectrograph
xNTD	eXtended New Technology Demonstrator