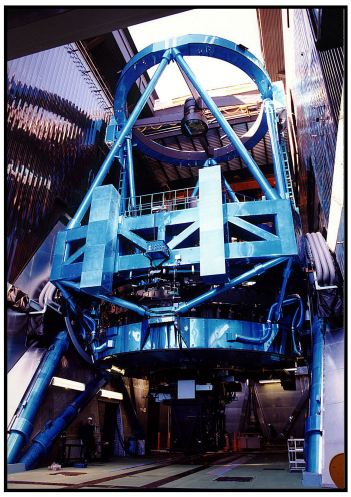
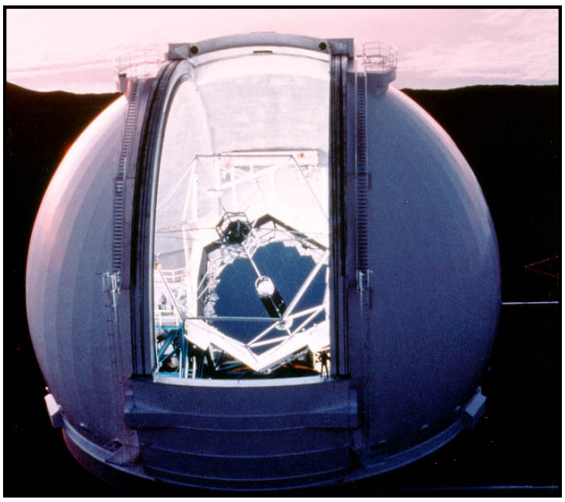
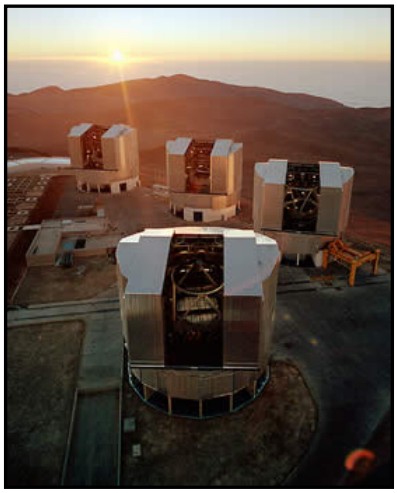




The Case For Additional 8m Access

A submission to the Astronomy NCRIS Strategic Options Committee (ANSOC)

Australian Gemini Steering Committee



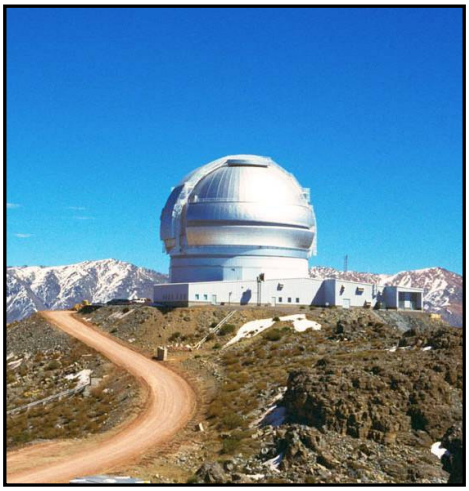


Table of Contents

Membership of the Australian Gemini Steering Committee:

Prof Warrick Couch (Swinburne) – Chair
Prof Matthew Colless (AAO)
Dr Scott Croom (USydney)
Prof Gary Da Costa (RSAA/ANU)
A/Prof Michael Drinkwater (UQ)
Prof Karl Glazebrook (Swinburne)
Mr Len Marsden (ARC)
Prof Peter Quinn (UWA)
Dr Stuart Ryder (AAO)

Cover images: top row (left to right) – Gemini North 8.1m telescope, Subaru 8.2m telescope, Keck 10m telescope; bottom row (left to right) – Magellan 6.5m telescopes, ESO 8.0m VLT telescopes, Gemini South 8.1m telescope.

The Case For Additional 8m Access

Executive Summary

Australia's well deserved international reputation for high quality research programs based around access to front-line optical and infrared observing facilities will be substantially enhanced by use of 'Strategic Options' funds to increase community access to world-leading 8m-class telescope facilities. We propose a multi-facility approach, seeking both additional share (funded by the ARC) and time (funded through the ANSOC process) on the Gemini telescopes, and continued access to the complementary facilities of the Magellan telescopes (ANSOC funding). A possible time-swap between the AAT and ESO may also permit community access to the VLT on a no-exchange of funds basis. Overall the proposed package would increase the community's access to the equivalent of 28.3% of an 8m telescope for the duration of the program, surpassing the (minimum) requirement of ~20% of an 8m outlined in the Decadal Plan. The funds sought from the ANSOC process total US$3.823M over the remainder of the NCRIS program.

1. Introduction

1.1 Overview

The last decade and a half has seen the emergence of the 8m-class[1] of optical/infrared telescopes as the largest and most powerful research facilities operating at these wavelengths. More than a dozen such telescopes have been successfully constructed and are now in routine operation as common-user facilities. By virtue of their unrivalled light-gathering power and their excellent imaging performance, they have opened up a myriad of new scientific opportunities across all the key areas of astrophysical study.

In looking to the future, 8m optical/infrared telescopes will further cement their position as the front-ranked research facilities world-wide, both through the transformative science discoveries they are poised to make in such areas as exoplanet imaging and characterisation, galactic archaeology, and dark energy science[2], and through their increasing 'work-horse' role in enabling individual investigator-driven science. Underpinning this will be the availability of a new generation of innovative instruments that will open up unexplored regions of 'discovery space'. Key examples in this context include more advanced applications of the now maturing adaptive optics (AO) technologies (such as extreme- and ground layer-AO) that use laser guide stars, and possible construction of the WFMOS instrument, which would provide a wide-field (degree-sized) highly-multiplexed optical spectroscopy capability on an 8m for the first time.

Within the context of Australian astronomy, 8m-class telescopes will also be integral to maintaining the strong synergies and coherence between the optical and radio domains. The Australian Square Kilometer Array Pathfinder (ASKAP) facility, which will come on-line in 2012, will be a powerful wide-field survey radio telescope. It will produce a plethora of objects that will require follow up at optical and infrared wavelengths, and here southern hemisphere 8m telescopes will have a critical role to play. This will encompass such areas as galaxy evolution, supernovae and transient studies, and high redshift radio galaxies and QSOs.

Clearly then, stable and long-term access to 8m-class telescopes is essential if Australia is to maintain its excellence and international competitiveness in optical/infrared observational astronomy, and reap the full scientific potential of its future radio facilities. Furthermore, that

[1] We include in this class, telescopes with an effective primary mirror diameter in the range 6.5 – 10 meters.
[2] Which on Gemini, will involve large 'campaign' science programs.

access needs to be at a significant level if it is to undertake scientific programs of major scope and impact. This need is firmly articulated in the current Australian Astronomy Decadal Plan[3], with *access equivalent to 20% of an 8m telescope* being set as one of the community's highest priority goals for the 2006-2015 period. Moreover, the Decadal Plan advocated this be achieved through continued membership of Gemini as well as increasing and diversifying our 8m access.

1.2 Current status of Australian 8m access

Australia has had direct access to 8m telescopes for more than 8 years, through its membership of the Gemini partnership. This provides Australian astronomers with access to twin 8.1m telescopes at two of the best mid-latitude sites in the world – Mauna Kea in Hawaii and Cerro Pachon in Chile. Currently, Australia is a 6.19% share partner in Gemini, which gives its astronomers up to 18 nights per year on each of the two Gemini telescopes (or effectively 36 nights or a 12.4% share of a single 8m telescope). Additionally, it has returned more than A$10M to Australia in instrumentation work, with Gemini contracting RSAA/ANU to build NIFS and GSAOI, and the AAO to undertake feasibility and concept studies for WFMOS, as well as earlier concept design studies.

Major National Research Facility (MNRF) funding has also been used to increase Australia's 8m access through the purchase of nights. A total of 24 nights on Gemini-South were purchased from the UK over the semesters 2005B-2006B. More recently, 30 nights on the Magellan telescopes (15 in each of the years 2007 & 2008) have been purchased. These cost US$46K per night, half of which is paid for in-kind, through the provision of two Australian Magellan Fellows who provide scientific and technical support at the telescopes. Having access to the Magellan telescopes has ensured that the Australian community's scientific needs are better met through, for example, provision of a high resolution optical spectroscopy capability that is not available on Gemini. The Magellan telescopes also offer a wide-field capability that the Gemini telescopes lack. Consequently, the Magellan time has been in high demand, being oversubscribed by factors of ~2-3. Given this importance, Astronomy Australia Limited has sought and been granted a 6 month extension to the current two year access arrangement, so that it not lapse prior to the ANSOC process.

While this combination of share in Gemini and nights on Magellan goes a considerable way towards meeting the Decadal Plan goal of 20% 8m access (the two amount to 15.9% of an 8m), the current level of access is quite limiting in the way these facilities are exploited scientifically. It is clear from the now well-established usage patterns that Australia's relatively small share of Gemini very much restricts the type of science programs undertaken on this facility, in terms of their size, scope and ambition. A large fraction (~65% in recent semesters) of Australian programs involves observations that are simply supplementary to major programs being undertaken on the AAT (a telescope of which Australia has nominally 87.5% of the time). Very few of the Australian Gemini observing programs involve major scientific projects being conducted solely (or primarily) on 8m telescopes. The same very much applies to Australia's use of its Magellan time. In addition, our 8m access is not been maximally exploited for postgraduate training, with very few Australian PhD theses being wholly or mostly based on Gemini/Magellan observations. Here the risk associated with getting the required quantities of observing time over a number of semesters is regarded as unacceptable.

[3] *New Horizons, A Decadal Plan for Australian Astronomy 2006 – 2015*

1.3 Current opportunities for additional 8m access

At the present time, there are five 8m-class telescope facilities worthy of consideration for Australian access[4]; these together with their status in terms of access can be summarised as follows:

- *Gemini* – After signalling last November its intention to withdraw from the partnership, the UK has since recommitted to continuing as a member, but indicated its intention to sell up to half its time (~63 nights per year, equivalent to a 11.9% share) to either other partners or external parties. The UK is looking to divest this time either through the disposition of share or the sale of nights.
- *Magellan* – Australia has an option to renew the current access arrangement for at least another two years. This would provide it with 15 nights per year on the 6.5m Magellan telescopes, with Australia continuing to provide two "Magellan Fellows" who each spend two years in Chile providing telescope support, followed by a year of research in Australia at a host institution of their choice. There is no option for Australia to acquire share in Magellan.
- *ESO/VLT* – Interest has been expressed by ESO in swapping VLT time for AAT time, due to their desire to have access to a more powerful wide-field multi-object spectrograph capability[5]. Whether this will proceed and how much time will be involved is yet to be negotiated.
- *Keck* – The recent opportunity to gain access to this facility via Caltech has passed, with Swinburne and Yale Universities taking up this option. However, membership of Gemini provides access to Keck through the time-swap arrangement these two observatories have, with up to 5 nights per semester being available to the Gemini partnership to use the high resolution optical spectrograph, HIRES. It is possible that this time swap might be expanded in future to include more nights per semester and access to other instruments.
- *Subaru* – Membership of Gemini also provides access to the 8.2m Subaru telescope, with up to 6 nights per semester being available to use Suprime-Cam (wide-field CCD imager) and MOIRCS (near-infrared imager and multi-object spectrograph). We note that this access to Subaru, as with the above access to Keck, only comes through having *share* in Gemini.

The key opportunities for Australia gaining additional 8m access in the short-term (i.e. the next 2-3 years) therefore reside in Gemini and Magellan, with there being some possibility of gaining access to the VLT through a swap of AAT time. This ANSOC submission and the plan that is presented for obtaining additional 8m access are therefore built primarily on the Gemini and Magellan options. The remainder of this document is devoted to presenting the details of this plan, along with its scientific and other benefits, costs and risks.

2. Proposed Plan for Additional 8m Access

In constructing a plan for additional 8m access, the following two issues require careful consideration: (i) whether immediate access to a facility has longer-term strategic benefits, and (ii) exactly how much access to a facility should be acquired. For the latter, the current Decadal Plan "equivalent of 20% of an 8m" goal sets a baseline target for the total amount of access, and which has the mandate of the community. However, it is the AGSC's strong view that Australia's access to 8m telescopes needs to increase *by at least a factor of two* over its current levels if its research community is to fully mature in its scientific exploitation of these facilities

[4] In that they operate in a well supported common-user mode and are equipped with a sufficiently broad suite of front-line instrumentation to cater for the scientific needs of the Australian community.

[5] That is provided by the AAOmega instrument, which in the future will be supplemented by a high spectral resolution mode (HERMES).

and their utilization as a research training tool. For Australian astronomy, this is an essential step in its development if it is to remain a significant force in optical/infrared astronomy internationally. On this basis, the following four-pronged plan is proposed which meets this overall target over the remaining lifetime of the current NCRIS program, and at the same time provides diverse and yet significant access to a number of facilities. The elements of this plan, along with the level of access (in terms of equivalent % of an 8m, and numbers of nights per year), duration and the key longer-term strategic benefits of each, are summarised in Table 1.

As can be seen, the plan for additional access involves three 8m facilities, Gemini, Magellan and VLT, with nights potentially being acquired on all of them. The purchase of an additional 4% share in Gemini is also envisaged. The time swap of AAT nights for VLT nights is still under negotiation, so this option must be regarded as provisional at this stage. If it does proceed, then importantly it would involve only a simple swap of time (with an appropriate number of AAT nights swapped for each VLT night) without any cash payment. Indeed, while a portfolio of four 8m access options is proposed, *only two of these options require funding from the NCRIS Strategic Options monies* (as indicated by the shaded rows in Table 1), with the Australian Research Council (ARC) being willing to pay the full cost (Operations + Aspen) of an additional 4% share in Gemini to be purchased from the UK.

The costs for the different access options are listed in two tables: those for the two options requiring ANSOC funding are given Table 2, whereas those for the "additional 4% Gemini share" option, including the full costs of the Aspen program running out to 2015, are given in Table A1 in the Appendix.

Table 1: Elements of the Proposed Additional 8m Access Plan

Facility	Access Option and Duration	Funding Source	% 8m	Nights (/yr)	Long-term strategic benefits
Gemini	Purchase share – 4% (on-going)	ARC	8	22[a]	• Greater influence and equity in facility. • Increased representation on Gemini Board and key committees (to be negotiated). • More influence and a greater return on WFMOS. • Preparing Australia for ELT era through development and use of key AO technologies. • Greater access to Keck & Subaru.
Gemini	Purchase nights – 2.2% (3 years)	ANSOC	4.4	12[a]	• Marker for additional share purchase in future.
Magellan	Purchase nights – (Present access arrange-ment to continue for another 2.5 years)	ANSOC	3.5[b]	15	• Valuable stepping stone to future involvement in GMT. • Diversifies access and mitigates risk with any individual facility.
VLT	Time swap with AAT (to be determined)	AATB	TBD	TBD	• Strengthen links and collaborations with ESO and Europe. • Scientific synergies between VLT and AAT. • Diversifies access and mitigates risk with any individual facility.

[a]Based on there being ~280 nights per year per telescope available to the partners, after accounting for host country/institution time, Director's discretionary time, Gemini staff time, commissioning and engineering time.
[b]Normalised to Gemini in terms of aperture area and partner nights per year.

The additional nights purchased on Gemini are costed at the appropriate operations-cost-only amount (US$60K per night). This is the price the UK has indicated it is willing to charge for its nights and there is no capital recovery component. Actual negotiation with the UK may yield a lower price per night. The Magellan nights will be acquired through a continuation of the current access arrangement, at the same price of US$46K per night, and are costed accordingly. Only half of this money is paid to the Carnegie Observatories; the other half is retained within Australia to pay for the salary, travel and on-costs of the two Magellan Fellows, which includes an additional 1.25 years at an Australian institution[6].

Hence what is proposed is a package which doubles Australia's access to Gemini (from 6.2% to an equivalent share of 12.4% for the duration of the program), maintains its access to Magellan at the current level (equivalent to 3.5% of an 8m), and possibly gives some access to the VLT, for an investment of only US$3.823M of the ANSOC funds. Overall, for the duration of the program, the proposal would increase Australia's access to the equivalent of 28.3% of an 8m, and provide its astronomers with 34 more nights of time per year on 8m-class facilities above the current Gemini share plus Magellan nights total. While the AGSC strongly recommends that ANSOC endorse and fully fund this multi-facility approach, the continuation of the current Magellan program is regarded as a higher priority than the purchase of additional Gemini nights, if full funding cannot be allocated. This prioritisation is based on the complementary nature of the Magellan instrumentation suite compared to that of the Gemini telescopes.

Table 2: Cost of ANSOC-funded Additional 8m Access Options (US$M)

Option	2009	2010	2011	Total
Gemini: Purchase nights – 2.2%	0.682	0.699	0.717	**2.098**
Magellan: 2.5 yrs @ 15 nights/yr	0.345	0.690	0.690	**1.725**
Totals	1.027	1.389	1.407	**3.823**

Assuming an exchange rate of A$1 = US$0.90, the total cost is equivalent to A$4.25M.

Finally, Table 1 also shows at a glance the longer-term strategic benefits that underscore each of the access options. The key points for Gemini are the increased influence and say Australia will have in the running of this facility through the acquisition of additional share, as well as ensuring Australia will reap greater scientific and instrument contract benefits from its considerable intellectual and financial investment in the WFMOS instrument. For Magellan, the connection and overlap this provides with the US institutions involved in the Giant Magellan Telescope project is an important strategic alliance that needs to be maintained. These plus other strategic benefits are further elucidated in Section 4 below.

3. Scientific returns and Development Potential

The Australian astronomy community has reaped substantial scientific benefits from its current access to the Gemini and Magellan telescopes. Importantly, however, there are a number of new powerful instruments that are about to come on-line at both observatories. Consequently, increasing community access will provide an unprecedented opportunity to exploit these new capabilities and significantly broaden and extend the scientific returns. We now briefly discuss these new facility instruments.

[6] On the assumption that the current 2:1 ratio of years spent at Las Campanas Observatory providing Magellan support to years spent in Australia (doing research) will be maintained.

3.1 Gemini

The current and future Gemini instrument suite has been built up as part of a coherent instrument development plan. This science-led plan has had the full engagement of the Gemini community, through such mechanisms as the Aspen process.

New instrumentation development is largely focused on Gemini's known strengths of excellent sensitivity in the infrared and outstanding delivered image quality. Within the next 18 months three new instruments will be commissioned: the FLAMINGOS-2 infrared imager and spectrograph, the Multi-Conjugate Adaptive Optics (MCAO) system and the accompanying Gemini South Adaptive Optics Imager (GSAOI), and the Near Infrared Coronographic Imager (NICI). These will provide a range of revolutionary facilities to Australian astronomers. In the slightly longer term the first of Gemini's Aspen program instruments, the Gemini Planet Imager (GPI) should be available in 2011.

FLAMINGOS-2 (+MCAO + F2T2) (GS)

When FLAMINGOS-2 comes on-line on the Gemini-South telescope in the second half of 2009, it will provide both imaging and spectroscopic capabilities in the near infrared (0.95-2.4 micron) over a 6'.1 diameter circular field. It will also have a multi-object spectroscopy capability with resolutions R = 1200-3000 for objects within a 2'x6' quasi-rectangular field. FLAMINGOS-2 is also capable of working with Gemini South's Multi-Conjugate Adaptive Optics (MCAO) system, which gives uniform AO correction across a 2' field. This unique combination of "wide-field" AO correction and near-IR multi-object spectroscopy will enable major advances in a number of fields. For example, two of the key science areas of FLAMINGOS-2 with MCAO will be the high redshift Universe and star formation in our Galaxy, both active areas of research within our community. Further, a tunable filter, F2T2, is being manufactured for FLAMINGOS-2 intended to detect sources during the epoch of re-ionization at redshifts between ~7–10, again an area of active research in our community. Given the capabilities of FLAMINGOS-2, particularly when coupled to MCAO, and the breadth of possible research, there is likely to be very strong demand from our community to use this instrument on Gemini South. Obviously additional time on Gemini-S will help meet that demand, and indeed will likely allow more comprehensive science programs to be tackled.

NICI

NICI, the Near-Infrared Coronagraphic Imager, is a dual-channel, near-infrared (1-5 micron) coronagraphic imager for use on Gemini South. It is expected to be available for use from semester 2009A. NICI is optimized for detection of faint, sub-stellar companions of stars by utilizing the simultaneous spectral differential imaging technique. There will be a major Gemini campaign program focused on searching for planets that includes Australian involvement. The high performance of the AO system will also enable other 'PI' science programs. NICI will make Gemini highly competitive for direct planet detection, and position the community to make further breakthroughs when the GPI comes on-line.

GSAOI (+MCAO)

The Gemini South Adaptive Optics Imager (GSAOI) has been built specifically to make use of the exceptionally high imaging quality to be provided by Gemini South's MCAO system. The 4 infrared detectors in GSAOI will record 4096×4096 pixels of data with an image scale of 0.02 seconds of arc per pixel. The full detector mosaic has an 85" × 85" field of view. This wide field of view (in terms of the number of resolution elements) opens up a broad range of science. Many of the most exciting opportunities will be in resolving stellar populations in dense regions whether they are in relatively nearby galactic clusters or external galaxies out to the distance of the Virgo cluster. The excellent image quality will also allow detailed morphological examination of high redshift galaxies in the rest-frame optical. Again community demand for use of this instrument is very likely to be substantial.

Gemini Planet Imager (GPI)
The Gemini Planet Imager will be the first of the Aspen program instruments to be built and will be available for use in 2011. GPI is an extreme AO system, with its high order correction carried out by a 4096 actuator MEMS device. Together with a high performance coronagraph this will enable direct detection of gas giant planets at distances >5AU from their parent star. This is exactly the location of gas giants in our own solar system. GPI science aims are to establish the frequency of occurrence of giant planets and to provide observational input to test planet formation models. GPI also has an integral field spectrograph which will record low resolution spectra of the detected planets, and which potentially could detect water and ammonia clouds in planetary atmospheres.

Current Gemini instrumentation
In the table below we summarize the currently available facilities on Gemini:

Optical	Near-infrared	Mid-infrared
Gemini North		
GMOS – long-slit, MOS, IFU spectrograph & imager	NIRI – imager & low res spectrograph (AO-fed)	Michelle – imager and spectrograph
	NIFS – IFU spectrograph (AO-fed)	TEXES – high res echelle spectrograph
	GNIRS – long-slit spectrograph (AO-fed)	
	ALTAIR – facility AO system (natural & laser GS)	
Gemini South		
GMOS – long-slit, MOS, IFU spectrograph & imager	Phoenix – high res spectrograph	T-ReCS – imager & spectrograph

3.2 Magellan
The twin Baade and Clay Magellan telescopes in Chile perfectly complement the resources available on Gemini. While Gemini focuses on the infrared and exceptional imaging quality over relatively small fields of view, Magellan has a suite of instruments which include a high resolution optical spectrograph and wide-field optical imaging and spectroscopy capabilities. Such capabilities are not available at Gemini. Like Gemini, Magellan is also developing a number of new instruments. These include:

FourStar
The FourStar infrared imager effectively replaces the current near-IR camera PANIC. It is a wide field imager using 4 close packed 2048x2048 HAWAII-2RG arrays to give a $10.9' \times 10.9'$ field of view. This instrument will be used in a variety of projects from cosmology to star formation in the Milky Way.

Carnegie Planet Finder Spectrograph
The Carnegie Planet Finder Spectrograph (PFS) is a high resolution echelle spectrograph being constructed for use at the Nasmyth focus of the Clay telescope. Its primary scientific objective is the detection of extra-solar planets through monitoring of stellar radial velocity variations with a precision of 1 metre/second. The spectrograph is currently under construction and is scheduled for delivery to the telescope late in 2008.

GISMO
GISMO (the Gladders Image-Slicing Multi-Slit Option) is an 8-fold field reformatter for the entrance aperture of the IMACS spectrograph, based on the concept of an image slicer. GISMO allows one to focus the entire large field-of-view of the powerful IMACS spectrograph on a central region, and thereby gain an 8 times greater density of slits in this region thereby. This will be of great utility for studying objects which are less extended than the IMACS field; for example the cores of galaxy clusters, or the individual components of nearby galaxies. GISMO is available for use from 2008B.

Current Magellan Instrumentation
In the table below, we summarize the current Magellan facilities:

Baade	**Clay**
PANIC – near-infrared imager	LDSS3 – optical low resolution MOS
IMACS – optical wide-field imager + MOS	MIKE – optical high res echelle spectrograph (inc. MOS)
MagIC – Optical CCD imager	MagE – optical/UV spectrograph

4. Other benefits

While increased access to 8m-class facilities will have direct research productivity gains for the community, there are also a number of less direct benefits that will accrue from the additional access. We now briefly describe these additional benefits.

Develop and enhance Australian astronomy
While most optical and infrared astronomers in Europe and the USA already consider 8m-class telescopes as their "workhorse" facilities, access to such telescopes for Australian astronomers is still so precious that it is generally utilised for only the most challenging of targets, or projects which are limited in scope and conservative by nature. Yet, as major projects with Australian leadership or involvement on the UKST (RAVE, 6dFGS) and AAT (2dFGRS, 2QZ, AAPS, WiggleZ), and Joint Programs on Gemini (GDDS, GRB follow-up) have demonstrated, genuine survey-scale programs on 8m-class telescopes result in more "revolutionary", as opposed to "incremental" science. The proposed substantial increase in 8m-class telescope access will allow the community to move to a mindset in which substantial programs on 8m-class facilities become the norm rather than the exception; such programs generally have a much longer lasting scientific impact than current small programs. These benefits flow from both increased share and increased telescope access through purchased nights.

Increased strategic influence
At the 10% share level within the Gemini partnership, Australia would be justified in seeking to have a second voting Board member. For reference, Canada has a 15% share of Gemini and two Board members. An extra Board member would give Australia more influence in steering the future course of Gemini in our interests, particularly when the current Gemini partnership agreement comes up for renegotiation in the period 2010-2012.

Increased instrumentation contract returns
Current Gemini policy seeks to ensure that each partner receives instrumentation contracts in proportion to partner share. Consequently, increasing Australia's share directly translates, under current policy, to increased instrumentation contract returns. This is particularly relevant in the case of the WFMOS project: while the AAO is leading one of the two WFMOS concept design teams, Australia's current small share in Gemini (and the previous GSAOI construction

contract) severely compromises its ability to take on significant portions of the work, and hence see Aspen instrument program funds come back to Australia. Increasing Australia's share in Gemini would therefore give it proportionately more return on its Aspen investment through increased WFMOS involvement.

Building experience with Adaptive Optics
Adaptive Optics and AO-fed instrumentation is of increasing importance in driving astrophysical research outcomes, and will be even more so in the Extremely Large Telescope (ELT) era, where the success of these next generation telescopes will critically depend on such technology. Gemini is currently the only access Australia has to AO facilities, and the additional time and share sought will enable the community to develop the expertise to build AO-centred research programs and make best use of AO-optimised instrumentation. In due course, these outcomes will feed directly into the Ground Layer Adaptive Optics (GLAO) system that will be integral to the success of PILOT and to many GMT instruments.

Continuing the Magellan Fellowships program
While the Magellan Observatory offers an excellent instrument suite which is highly complementary to that available on Gemini, its status as a privately-funded consortium has meant that it has never been staffed adequately to provide the kind of national facility-level support that Australian users of the AAT, ATNF, and Gemini have come to expect and value. Thus, a critical aspect of Australia's original access agreement with Magellan stipulated that half of Australia's time would be paid for in the form of two postdoctoral-level Magellan Fellows, who would spend 2 years resident in Chile supporting general Magellan operations and carrying out research, followed by 1 year of research at an Australian institution of their choice.

This arrangement has been an outstanding success. For Magellan, it has enabled them to offer a much-improved level of observing support at the telescope for all their visitors, as well as carry out tasks such as writing documentation, improving calibration and data analysis software, capabilities that they previously lacked the resources for. For Australia, the benefit has been that observing at Magellan has not been the "poor cousin" of observing with Gemini, as well as the fact that two Australian institutions will benefit from having two full-time researchers for a year each. For the Fellows themselves, the opportunities to work alongside some of the top US and Australian astronomers, apply for Magellan time in their own right, and the chance to build their careers in Australia afterwards make these Fellowships particularly attractive. At the end of their terms in Chile they will bring a wealth of large telescope expertise back to Australia, together with lots of ideas and Magellan data to work on with new collaborators and students here and overseas. Renewal of the Magellan access program will enable new Magellan Fellows to be appointed, and give others the opportunity to work in such a stimulating environment.

Enhanced student training
Not only is the current available amount of Gemini and Magellan time considered too precious by the community to risk on more speculative programs, it is also often perceived as too risky to form the basis of a significant component of a student's PhD program. While approximately a third of Australian Gemini/Magellan users are PhD students, in the majority of cases their use of the time is not central to their thesis work. Feedback from PhD supervisors and students indicate that the high risk associated with getting Gemini and Magellan time – particularly in getting sufficient and continuous allocations at suitably high ranking to successfully execute a major observing program appropriate for a thesis study – is a major disincentive to contemplating the use of the Gemini or Magellan telescopes as a primary research training facility. Increasing Australia's access to Gemini, and maintaining the current access to Magellan, would give students and their supervisors the confidence to make greater use of these facilities, and so increase their value to education and research training.

A bridge to GMT

Although the GMT consortium and the Magellan consortium are distinct entities, there is a lot of overlap between the two. Continued access to Magellan therefore provides a natural pathway for Australian astronomers to build strong collaboration with colleagues at the partner institutions that are likely to have the lion's share of GMT observing time. There are already indications from Australian Magellan proposals that applicants are keen to pool their time requests (if successful) with related Magellan proposals led by their collaborators at prestigious US institutions such as Carnegie, Harvard, MIT, and the University of Arizona.

While paid membership of the GMT consortium is obviously essential to have influence and a proportionate share of observing time, Australia stands to gain so much more from GMT in the long run by fostering scientific relationships today, which could subsequently flourish into the science teams that will tackle the "big questions" with GMT. Historically, Australian representation in such teams has been much greater than its share of funding or observing time. But it was only through the sense of trust and intellectual respect built up over the course of many precursor international programs that Australian astronomers attained this status. While serving the needs of many individual Australian researchers, access to Magellan is also sowing the seeds for science to be done by and with Australians on the GMT.

Strength in Diversity

Membership of Gemini enables guaranteed access not only to Gemini's own facilities, but also to exchange time on other frontline facilities like Keck and Subaru, to which Australia would normally not have access by right. As exchange time observing runs must be classically scheduled in units of integer nights (with a typical cap of ~5 nights per semester per facility), Australia finds it harder to access this time than the bigger partners. An increased share of Gemini time therefore also leverages increased access to instruments not otherwise available to the Australian community.

Diversification of access across multiple facilities also has a positive benefit, by avoiding a monoculture and mitigating risks. As recent severe earthquakes in Hawaii and Chile have demonstrated, even well-prepared facilities like Gemini can be put out of action for several weeks by acts of nature. Political and budgetary factors can also hinder an observatory partner's capacity to contribute funding at critical times. Thus, it makes sense for Australia to maintain a balanced portfolio of access to both Gemini and Magellan, particularly as each in turn can open doors to other facilities elsewhere.

5. Feasibility, Robustness, and Risks

In this submission, we have presented a plan for acquiring significant additional 8m access, which we believe is both feasible and robust in terms of its delivery. More specifically, the two options that require ANSOC funding – the purchase of nights on Gemini and Magellan – can both be taken up without question, and the costs for each of these options are clearly defined up front. The UK have agreed to sell Australia Gemini nights at a fixed price, and the Magellan Council has given its in-principle agreement for Australia's current access arrangement to continue for another 2.5 years at the same per night cost. Both the Gemini and Magellan Observatories are now mature and stable telescope facilities with well supported and reliable instrumentation, and should remain so over the period the ANSOC funds would be used.

This notwithstanding, none of the access options come without some risk, the key ones being as follows:

- *Uncertainty of the Gemini partnership beyond 2012* – On 31 December 2012, the current International Gemini Agreement[7] expires, and a new one will have to be negotiated and entered into if the Gemini Observatory is to continue to operate beyond this date. There is the risk that the current partnership could be significantly diminished or disintegrate beyond 2012 – the UK, for example, have already indicated that their membership will end at this point[8] – thereby threatening the continued operations of the Observatory and disrupting the Aspen instrumentation program (which is now set to run well beyond 2012). While the UK has declared its position, the status of the other partners in terms of their continued participation and level of engagement in Gemini currently remains unknown. Hence it is difficult to quantify this risk (or indeed opportunity), although it is already clear that there will have to be a reconfiguration of the partnership to accommodate the UK's exit.

- *Uncertainty over the funding and future of the Gemini Aspen program* – Gemini's current Aspen instrumentation program, which is designed to equip the Gemini telescopes with the next generation of state-of-the-art instruments, has and will continue to be funded by the partners on a 'best efforts' basis. Uncertainties and difficulties all the major partners have had in making and meeting their financial commitments in the first three years of the program have seen it be delayed, descoped, and its time-line significantly stretched beyond its original 5 years. This situation is unlikely to change into the future. Moreover, and most importantly for Australia, whether the Gemini partnership has the financial and political capacity to proceed with the number one science priority of the Aspen program, WFMOS[9], remains unknown, and there remains a significant risk that the construction of this instrument will not proceed. If this were to be the case, then the Aspen program will have failed to cater for the scientific needs of the majority of the Australian community, making continued membership of Gemini less attractive. Note that this does not affect the scientific value of nights purchased during the NCRIS period, but rather is a concern in the longer term.

- *Purchasing nights does not buy influence* – An inherent weakness in the 'purchase of nights' options (on Gemini and Magellan) is that it does not increase Australia's influence in the facility. For Gemini, this is mitigated by the co-strategy of increasing Australia's share and hence its influence and representation. For Magellan, Australia will have no say in decision-making processes during the 2.5 year access period, and runs the risk that it would be powerless to oppose major operational changes such as the withdrawal of key instruments, or a change in the level and mode of operational support, that would negatively impact its scientific exploitation of this facility. However, no such changes are contemplated at the present time.

These are all serious risks, but they highlight a further strength of the package of additional access options that is being proposed, in that its diversity of access mitigates against these risks.

6. Concluding summary

This submission makes the case for the investment of A$3.823M of the NCRIS "Strategic Options" funds to provide the Australian astronomy community with additional 8m telescope access. This is part of a broader, long-term vision to more than double Australia's current level of access and, in doing so, reap substantial strategic benefits for optical/infrared astronomy as a

[7] To which the Australian Research Council is Australia's signatory.
[8] It should be noted that the UK's withdrawal in no way reflects on Gemini's current or future capabilities and operations; rather it is driven by the need to make substantial cost savings in the STFC's budget.
[9] Through reaching agreement with the Japanese to equally share the cost of WFMOS and put it on Subaru.

whole. A multi-facility approach is proposed, involving increased access through purchasing extra share (funded by the ARC) and nights (funded by ANSOC) on the Gemini telescopes, the continued purchase of nights on the Magellan telescopes (funded by ANSOC), as well as the possibility of a time swap of AAT time for access to the ESO VLT telescopes.

The case for more than doubling Australia's current level of access is predicated on the pivotal role such access will play in sustaining and growing the optical/infrared community and keeping it internationally competitive. Telescopes in the 8m class will be the front-line work-horse facilities for astronomical research over the next 10-20 years; access to them at a per-capita level comparable to our European and US colleagues is essential if optical/infrared astronomy in Australia is to continue to have a vibrant research community through the next decade and be in a position to fully exploit future facilities such as GMT and PILOT. Securing the future in this context is critically dependent on 8m telescopes becoming the primary research training tools of Australia's next generation of astronomers, which will only be possible if the level of access is significantly increased.

A diversity of access options provides the Australian community with a broad and complementary set of 8m instrument capabilities and mitigates risk (see §5). However, the continued access to Gemini and Magellan consolidates and builds upon Australia's well-developed use of these facilities. In particular, it will not only allow Australian astronomers to more aggressively and ambitiously pursue their PI-science programs through having more time, but will also present significant new scientific opportunities in the next 2-3 years through the introduction of new instrumentation and capabilities (particularly in AO).

Finally, it should be emphasised that this "additional 8m access" options package serves a broader purpose than just taking advantage of the near-term ANSOC funding opportunity; it also sets a goal and strategy for increasing Australia's 8m access in the longer term. Funding of this ANSOC option represents an important first step in achieving this important ambition, and putting Australian astronomy in a strong position to secure long-term 8m-class telescope access beyond the current NCRIS program.

Appendix

Table A1: Gemini share costs (US$M)

	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
Current 6.19% share								
Operations	1.919	1.967	2.016	2.067	2.119	2.172	2.226	14.486
Aspen	0.424	0.566	0.409	0.575	0.349	0.082	0.098	2.503
Total	**2.343**	**2.533**	**2.425**	**2.642**	**2.468**	**2.254**	**2.324**	**16.989**
Additional 4% share								
Operations	1.240	1.271	1.303	1.336	1.369	1.403	1.438	9.360
Aspen	0.146	0.238	0.264	0.371	0.225	0.053	0.063	1.360
Total	**1.386**	**1.509**	**1.567**	**1.707**	**1.594**	**1.456**	**1.501**	**10.720**
Grand Total	**3.729**	**4.042**	**3.992**	**4.349**	**4.062**	**3.710**	**3.825**	**27.709**

Notes: • Operations costs post-2010 assume continuation of annual 2.5% ramp.
• Aspen costs assume full construction of Gemini Planet Imager (GPI) and WFMOS, plus concept design study for GLAO.