A NY State Partnership with The Gemini Observatory

Response to New York Astronomical Corporation
Call for Concept Proposals for a NY State Telescope

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Executive Summary

The ASNY telescope survey identified the community priority for a NYAC telescope initiative as an optical, ground-based, multipurpose telescope, with both imaging and spectroscopy capabilities suitable for targeted observations and PhD thesis projects. Any one of the 16 operational optical telescopes larger than 6.5 meters could potentially satisfy these needs and could be immediately available through partnership, whereas embarking on a project to construct such a telescope would be an enterprise requiring least a decade and perhaps $100M or more. In the 2020+ timeframe, such a telescope would then be one of at least 16 large optical telescopes in operation, and competing with the next generation of extremely large telescopes (ELTs) larger than 20 meters.

The identification of a partnership with an existing observatory offers a short timescale to access with well known costs and performance. By partnering with an international, high profile observatory, NYAC could quickly provide an attractive resource for NY institutions to recruit faculty and students. One possible choice is the international Gemini observatory, which uses 8 meter mirrors cast by Corning in NY.

In 2013, the UK will withdraw from the Gemini partnership, resulting in a 25% reduction in the Gemini operating budget. The Gemini international partnership will be restructured, and the observing time redistributed. If additional funding is not forthcoming from existing or additional partners, Gemini must necessarily experience a serious contraction in its scientific staff and instrumentation development capabilities.

The science capabilities of the Gemini Observatories are already broad and deep, covering optical through infrared with areas of particular innovation being adaptive optics and thermal infrared capabilities. Gemini is unique amongst the large telescopes in covering both the northern and southern hemispheres. The Gemini telescopes are the most advanced in terms of deployment of adaptive optics capabilities that most closely mirror the science capabilities under consideration for ELTs, and will therefore be the training ground for the development of the generation of astronomers who will successfully exploit the ELTs.

The Gemini international agreement specifies that the instrumentation program will be executed by the partners in proportion to their partner shares, and so a NY State partnership with Gemini involving an instrumentation component developed within NY State is in keeping with the previous structure of the partnership. Indeed the strength in instrumentation at NY institutions would make a NY State participation compelling for the Gemini international partnership.

The funding model and partnership would involve a consortium of NYAC and NY institutions developing a partnership plan. This plan would include instrumentation programs; where possible, institutional financial commitments; and a proposal to the state legislature that starting in 2013, NY fund at a level comparable to the funding provided by other states (such as California, Arizona or Hawaii) a NY partnership with the Gemini observatory.

Science

The current generation of large optical telescopes has been motivated to address the broadest and most compelling set of science questions conceivable. Through updates to instrumentation, the scientific capability of these telescopes evolves to remain at the forefront. As the only premier international observatory covering both hemispheres, with a suite of versatile and developing instruments, Gemini can address a very broad range of science. The scientific direction of the Gemini observatory is regularly articulated and reexamined through proposals, reports, and the oversight of the observatory. Here we highlight only a few brief cases identified by NYAC members.

We also note that the nature of the astronomy observing proposal process is that there is a chicken and egg cycle: proposal calls prompt new proposals, which feed new scientific questions and approaches from their results. The nature of this cycle is evidenced by the disproportionate use of Gemini by astronomers resident in states with other large telescopes such as California, Arizona, and Hawaii. Historically, these three states have each received more than ten times the allocation of Gemini time (see Figure 5) than New York, presumably because of, not in spite of, their privileged access to other optical telescopes. The science cases identified here are merely the fertile seeds from which a larger enterprise will grow.

Kevin Covey (Cornell University): Young Stars
There is significant evidence to suggest that stars accrete the majority of their mass in intense accretion events such as those believed to cause FU Orionis outbursts. We lack detailed empirical constraints on the dynamics and duty cycles of these outbursts. Surveys are now covering large portions of the sky with regular cadence, removing the bottleneck of detection of these outbursts, but requiring detailed follow-up to track their evolution. With the leading suite of near- and mid-infrared instrumentation among 8-meter telescopes (e.g., Phoenix, Flamingos-II, NIFS, NICI, NIRI, T-ReCS, Michelle, TEXES), Gemini is able to provide detailed diagnoses of the heavily reddened outbursting sources. Gemini guarantees access to outbursts across the entire sky, and its queue-based scheduling is well suited to target of opportunity observations, as well as sequences of observations to track the evolution of outbursts over time.

Don Figer (RIT): The Life Cycles of Massive Stars
Massive star formation, evolution, and death remain theoretical challenges. Figure 1 highlights the life cycles of massive stars. The sketchy details that describe the transitions from each of the phases in the diagram have broad impact throughout much of astrophysics. These questions trace the life cycles of massive stars, from their birth in clusters to death as supernovae. They are compelling and highlight major missing links in our basic understanding of massive star formation, massive star evolution, and the impact of massive star clusters on surrounding environments. They are also timely, as the tools to answer them have only recently become available.

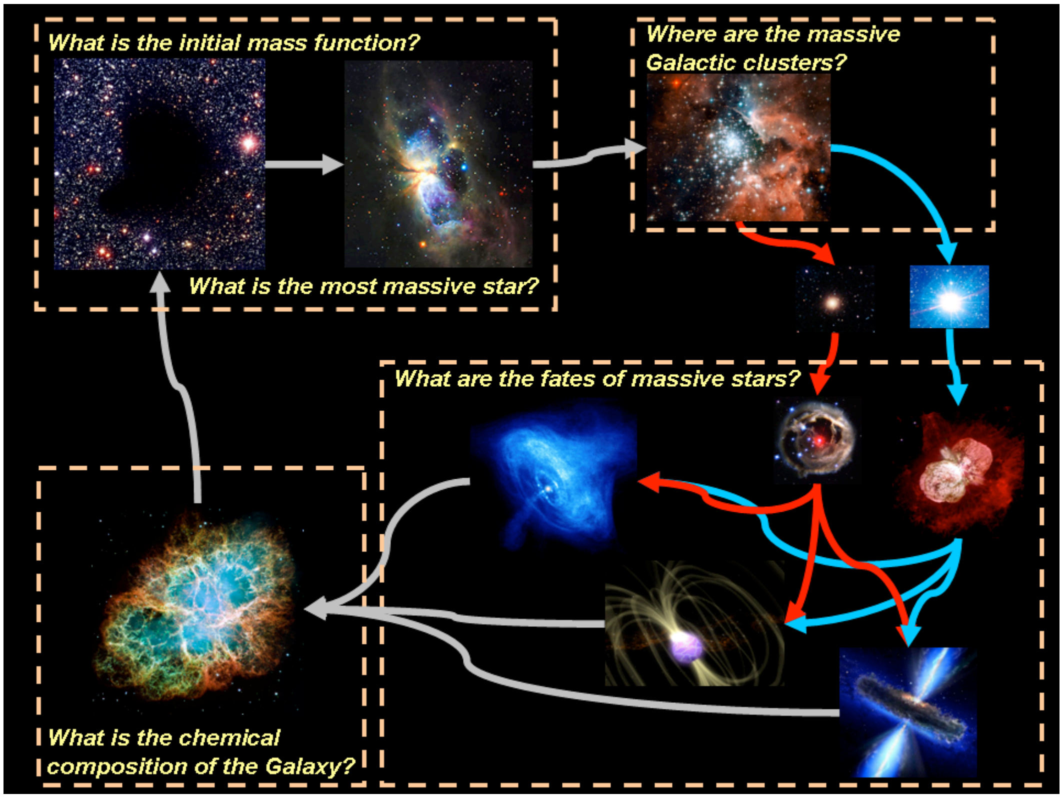

Figure 1. Star clusters and the life cycles of massive stars.Note the uncertainty between progenitor mass and end state, as demonstrated by the overlapping lines connecting neutron stars, magnetars, and black holes to intermediate mass stars that become red supergiants (red lines) and more massive stars that only become blue supergiants (blue lines); it is not clear which of these lines are accurate.

Stan Metchev (Stony Brook University): Studying Exoplanetary Worlds with the Gemini Planet Imager: Architectures, Evolution, and Atmospheres
The recent breakthrough of direct imaging of exoplanets has imparted a major new thrust to exoplanetary science. Images have opened new views into the structure and evolution of other planetary systems, and direct spectroscopic studies of exoplanetary atmospheres are in the immediate future. The Gemini Planet Imager (GPI) will be the first instrument that will decisively address these issues through the direct imaging of exoplanets. GPI includes an integral field spectrograph, a coronagraph, and a polarimeter. With interests in planet formation well-represented among the New York astronomical community, the Gemini telescopes would be a highly appropriate asset.

Thomas Nikola (Cornell University): AGN-Starburst Connection
Many galaxies host a massive black hole surrounded by a gas accretion disk producing a luminosity that can easily outshine the host galaxy (AGN). Vigorous starbursts produce stars at such a high rate that it would exhaust the available gas reservoir on a time scale much shorter than the lifetime of the galaxy. The starburst trigger mechanism and interaction of AGN and starburst is important for understanding the evolution of galaxies. In the early Universe, galaxy interactions were common, the gas reservoirs were larger, and the starburst and AGN activities were more vigorous. Gemini is particularly well suited to address these questions in the mid-IR wavelength regime.

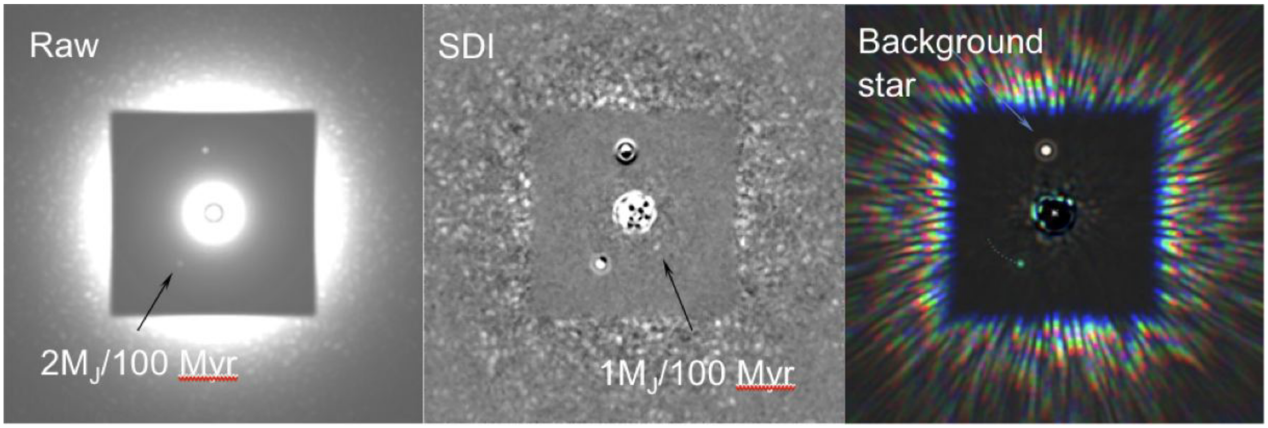

Figure 2: GPI simulation of a 100 Myr old K star at 17 pc with 1 and 2 M_j planets, and a background star seen in projection. Credit: C. Marois (HIA/DAO) The left panel shows a raw monochromatic cross section of the GPI data cube. The middle panel displays a reduced version using a spectral deconvolution approach. The right panel shows a wavelength-collapsed version of the GPI data cube, contrasting behavior of atmospheric and telescope speckles astrophysical point sources.

Michal Simon (Stony Brook University): Masses in Young and Old Binaries
The only way to resolve the discrepancies among the several calculations of pre-main sequence evolution is by empirical determination of stellar masses. Members of the nearby moving groups are beautifully suited for this purpose because many are in visual binaries, have HIPPARCOS parallaxes, and those that are resolvable by adaptive optics at the Gemini 8 meter telescopes have orbital periods of a few years. I would use the AO systems at Gemini to map their orbits and hence measure their total mass. Extension of low-mass members of the nearby young moving groups to stars of mass ~0.1 Msun is important 1) to provide high priority targets for exoplanet searches by direct imaging, 2) to complete the census of the membership, and 3) to provide a well-characterized sample of nearby young stars for detailed study of their physical properties and multiplicity. The candidate's radial velocity is essential to establish membership. I would use GNIRS for this purpose in the North, and PHOENIX at Gemini-S if it remains available.

Fred Walter (Stony Brook University): Physics of Recurrent Novae
Recurrent Novae (RNe) are unpredictable, and fade rapidly, so require rapid turnaround and large collecting area. Gemini is well suited to this problem by providing queue observing operations and the sensitivity for spectroscopic observations as the objects fade into quiescence. The goal is to look for subtle quasi-periodic variations on timescales of hours to a few days that may reflect binary orbital motions, characteristic accretion disk orbital timescales, or the white dwarf rotation. These oscillations seem to be most prominent 30-90 days after maximum light, when the nova is about absolute V mag -1 (V~17 in the LMC). A typical CV has orbital periods of 80 minutes to about a day, so orbital velocities are of order 100 km/s. Resolution of a few thousand will suffice, but we need to collect enough light in 10 minutes to detect the emission lines.

Hardware Design

The Gemini Observatory consists of twin 8.1 meter telescopes covering both hemispheres. Gemini North is located on the summit of Mauna Kea, and Gemini South at Cerro Pachón in Chile. Observatory construction began in 1993 under an international partnership. The primary mirror blanks were cast by Corning of Corning's proprietary low-expansion ULE glass. The first blank for Gemini North was delivered in October 1995 followed by the Gemini South blank in May 1997. Both telescopes began science operations over the period 1999-2002. The Gemini telescopes are particularly efficient in the infrared, having total telescope emissivity less than 2% due to a silver coating. The Gemini observatory has led the development of adaptive optics, and is fielding the first multi-conjugate adaptive optics system and the first extreme adaptive optics system, the Gemini Planet Imager.

The estimated lifetime cost of Gemini is $547.1M through 2010[1], including $122.4M in expenditures on instrumentation developed by universities and institutions within the partner countries. Each telescope is configured with a support structure that supports five simultaneously mounted instruments on the five available faces of a cube.

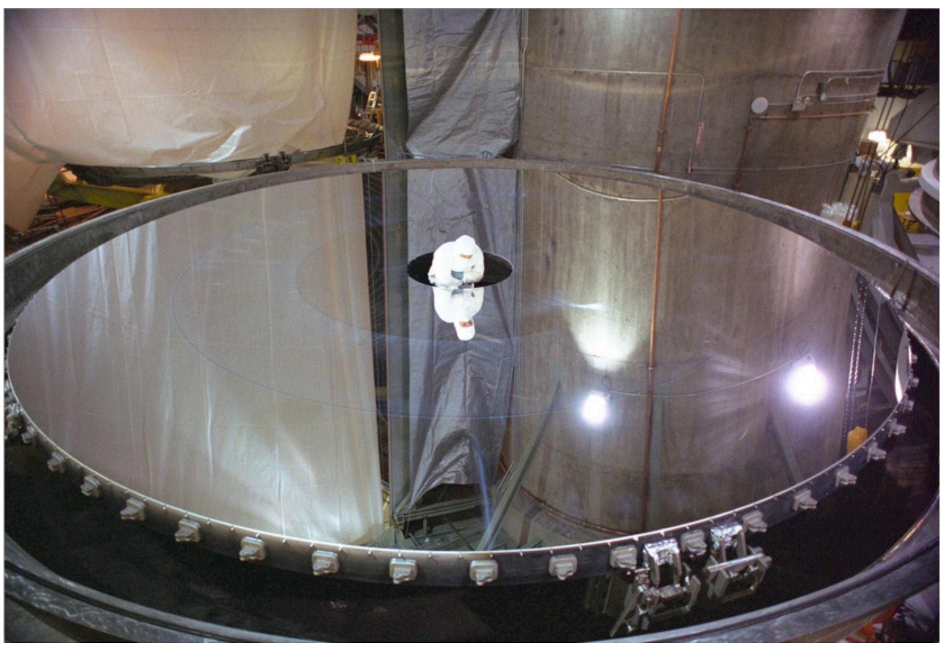

Figure 3: Gemini North Primary Mirror after first coating (Gemini Observatory/AURA)

[1] Jean-Rene Roy, " The Gemini Observatory: Challenges and Benefits of Operating an International Facility, presentation at 9th Project Science workshop, October 21 2009

The current instrument portfolio is:

Gemini North

GMOS	optical multi-object, long-slit and IFU spectrograph and imager
NIRI	1-5μm imager with grism spectroscopy
GNIRS	1-5μm long-slit and 0.9-2.5μm cross-dispersed spectrograph
Michelle	10-20μm imager/ spectrometer; imaging polarimetry
ALTAIR	facility natural/laser guide star AO system
NIFS	1.0-2.5μm integral field spectrograph
TEXES	visiting 10-20μm high resolution spectrograph
GCAL	facility calibration unit

Gemini South

GMOS	optical multi-object, long-slit and IFU spectrograph and imager
Phoenix	visiting NIR high resolution spectrometer
T-ReCS	formerly known as MIRI; imager and spectrometer
GCAL	facility calibration unit
NICI	coronagraphic imager
MCAO	Canopus Multi-conjugate adaptive optics system
FLAMINGOS-2	NIR multi-object spectrograph
GSAOI	high-resolution imager for use with MCAO

Under development is the Gemini Planet Imager, to be delivered to Gemini South in 2011. Along with the Gemini instrument capabilities, time is exchanged with other telescopes, resulting in Subaru and Keck being available through the NOAO Gemini TAC.

Operational Concept

The current Gemini partnership expires on 31 December 2012. Current partner shares (fraction of operations cost contributed) are

USA (National Science Foundation)	50.1%
UK (Science & Technology Facilities Council)	23.8%
Canada (National Research Council)	15.0%
Australia (Australian Research Council)	6.2%
Brazil (Ministério da Ciência e Tecnologia)	2.4%
Argentina (Ministerio de Ciencia, Tecnología e Innovación Productiva)	2.5%

Non-financially contributing partners are the University of Hawaii and CONICYT, which receive 10% of the time on Gemini North and South respectively in return for in-kind contributions of site operations facilities.

In December 2009, the UK announced its intention to withdraw from the partnership at that the expiry of the current partnership agreement. The Gemini board has indicated the possibility of additional partners or increases in the financial contributions from individual partners in return for increased shares. In the absence of additional forthcoming funding, the Gemini observatory faces a severe budget shortfall. The Gemini observatory has prepared a transition plan for a scenario with a 20% budget reduction. To realize this budget, Gemini will reduce the staff size by 32 FTEs, reduce capabilities to four instruments plus adaptive optics at each telescope, transition to fully remote nighttime observing, and curtail new instrumentation development.

The Gemini partnership is open to the addition of new partners. Given the expectation that state funding would not be forthcoming unless it were predominantly expended within NY State, we envisage a partnership based primarily on an in-kind contribution of instrumentation. Although Gemini has historically been reluctant to consider in-kind contributions, and it is likely that the determination of the share of telescope nights would be less favorable than for a cash contribution, such a partnership fulfills many needs of both Gemini and the astronomy community in NY State.

Expertise within NY State is remarkably well suited to the needs of Gemini instrumentation. Current expectations are that NIRI, T-RECS, and NICI will be decommissioned over next few years, leaving Gemini North without NIR imaging and Gemini South without mid-IR capabilities. Beyond GPI there is no instrument under development. Two instrument concepts Gemini would pursue if available are IR imager with H4RG detectors and X-Shooter-like spectrograph. Expertise already exists to rapidly develop these instruments within NY State institutions.

Time to Completion

Obviously, as an operational facility, Gemini would be available to the NY State community as soon as NYAC put into place an agreement. However, it should also be

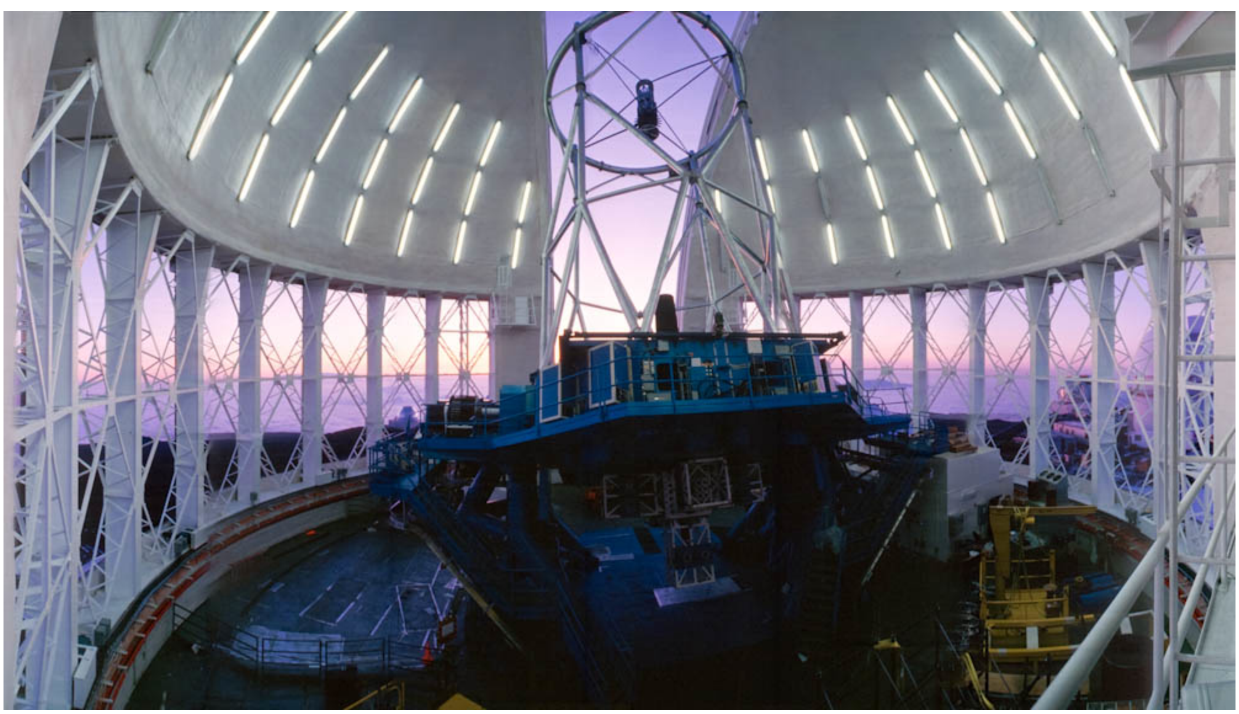

Figure 4: Gemini North telescope at twilight (Gemini Observatory/AURA)

recognized that a boost to the O/IR observational community would be generated as soon as it appeared possible that NYAC may join Gemini. Historically, the broader NY astronomical community has not been a large user of Gemini or any other large optical telescope. Despite containing roughly 5% of the AAS membership and ranking as the 5th largest state by number of AAS members, NY has only used 0.9% and ranks 18th in terms of total allocation of Gemini time over the last 7 years.

For NYAC to be successful in any optical telescope enterprise, it will be essential to expand the size of the user base within NY State. Although any operational telescope would be available upon the commencement date of an agreement, since Gemini is already available to the NY community through the NOAO TAC, the prospect of enhanced future access to Gemini would immediately stimulate astronomers within NY State to execute proposals for projects that may be in development or below their current threshold of attention. Therefore, even well in advance of the execution of an agreement or full funding, NYAC pursuing efforts towards a Gemini partnership would yield dividends in the form of boosting NY State involvement in O/IR large telescopes.

Since the NOAO TAC serves a very large community and handles a large number of proposals, there is a tendency for the available time to be sliced into a large number of small allocations. With the current trend toward large survey programs in astronomy, a TAC serving a small community enables long-term and larger programs. Although the NOAO TAC solicits for proposals for large surveys, only one such program has ever been approved for Gemini since 1999 (http://www.noao.edu/gateway/surveys/programs.html). The prospect of stable access would encourage astronomers to develop proposals for large projects, and provide those proposals with a competitive edge.

Gemini has been criticized for excessive operations costs, and for failing to provide the instrumentation capabilities expected by the community. In response to these criticisms, restructuring the Gemini governance and operations is already underway as a new partnership agreement is developed. Joining the Gemini partnership now will place NY State astronomers in a position of leadership in defining the future of US ground based astronomy.

Response to the mission statement and survey

The NYAC telescope mission statement identifies its central goal, as providing access to world-class facilities to the astronomical community in NY State. The ASNY telescope survey identified the community priority for a NYAC telescope initiative as an optical, ground-based, multipurpose telescope, with both imaging and spectroscopy capabilities suitable for targeted observations and PhD thesis projects.

Fulfilling all these goals simultaneously within any plausible funding scenario will be a major challenge. The cost of world class telescope facilities has now reached the point that new facilities are beyond the reach of single institutions, consortia of institutions or even individual countries. The next generation of facilities are uniformly being built by international consortia. Even the currently operational large optical telescopes have become international partnerships. A singlehanded undertaking of a genuinely world-class facility, therefore, will require resources comparable to those of the consortia

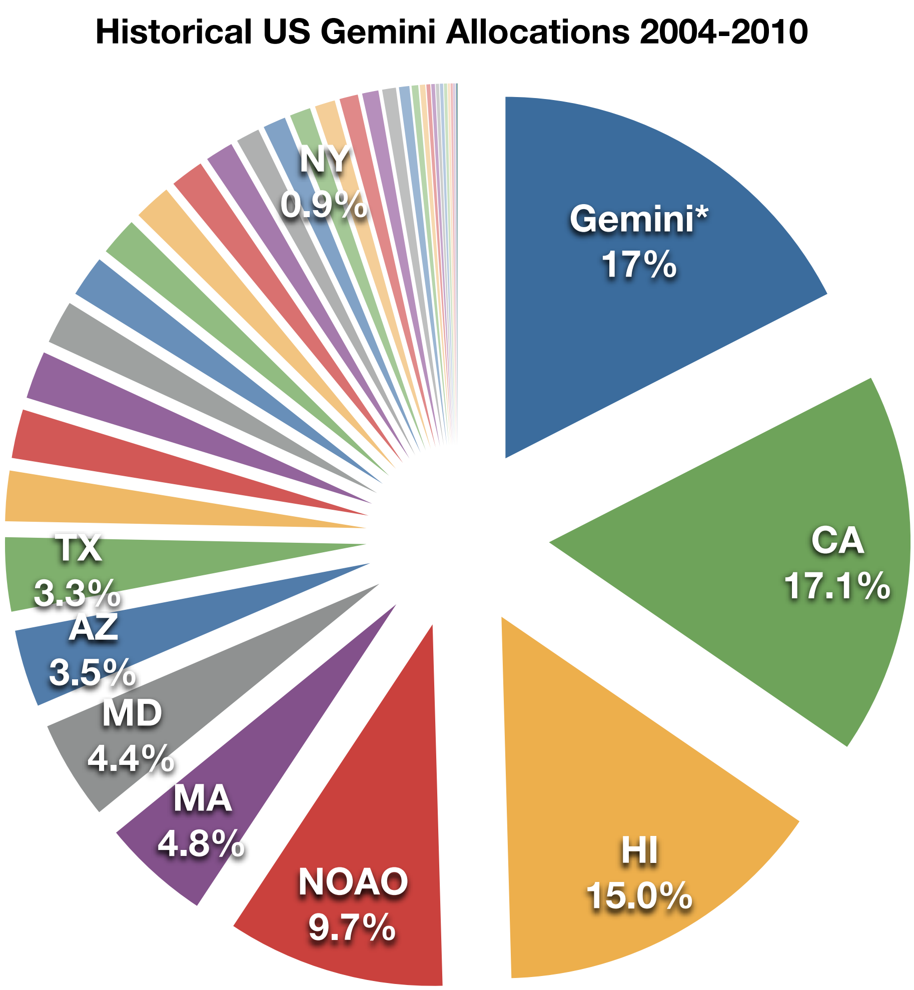

Figure 5: Historical US Gemini allocations 2004-2010. Source: Gemini observing database PI email addresses.
** The summation of allocations under Gemini includes Director's Discretionary, Science Verification and poor weather backup programs. Due to large allocations of backup programs to use telescope time that would otherwise be unusable, this slice is not directly comparable to the other allocations.*

operating existing world-class facilities. Given the likely scenarios of NY State funding, participating as a stakeholder in such a facility is surely the only reasonable path forward for NYAC to provide access to a world-class facility.

Gemini is clearly world-class, and even with the current suite of instrumentation is directly suitable for the broad multipurpose imaging and spectroscopy capabilities for projects across a breadth of scales identified in the ASNY survey. Given that the without an additional partner Gemini faces a drastic reduction of instrumentation development, a NY State partnership that invigorates development of Gemini instrumentation places the participants in NYAC in a position to lead the next generation of instrumentation.

Two instrument concepts Gemini would pursue if available have already been identified as clearly aligned with NY State institutions capabilities and interests: an IR imager with H4RG detectors and an X-Shooter-like spectrograph.

The development of a NY operations and observation center naturally meshes with the Gemini transition plan to remote observing and would respond to desires expressed in the survey to have a spectrum of observing approaches (queued, remote and classical). Gemini has always been receptive to requests for classical observing, and will be able to provide both the efficiency of queue observations and a world-class facility with which students can interact and learn.

Finally, participation in an observatory, rather than construction of a new one, offers adaptability towards future possibilities. The entity that is created to partner with Gemini will be a center for the construction of instrumentation and execution of observations. Decades from now the landscape of observational needs and capabilities will surely be dramatically different. Rather than being fixed to the operations of a particular piece of hardware, NYAC will be able to evolve toward participation in larger telescopes and facilities.

It is difficult to imagine that anybody would have correctly forecast even 20 years ago that there would be 16 telescopes of aperture 6.5 meters or larger operational in 2010. How many ELTs might there be in 2030? Regardless, it is absolutely clear that the generation of ELTs will be built with adaptive optics central to their capabilities. Although Gemini has been criticized for excessively emphasizing infrared capabilities at the expense of traditional optical capabilities desired by the community, this is partially a result of Gemini being the first telescope that was conceived in the same adaptive-optics driven model as the ELTs. The Gemini telescopes are now utilizing adaptive optics in much the same way that ELTs will, and the astronomers and astronomical programs that succeed with the current configuration of Gemini will be the most likely to succeed using ELTs.

Funding Model and Partnership

This partnership is open to all astronomers in NY State, and presently does not favor any particular institution or have any institutional commitments for funding or other resources. Assuming this option were selected by NYAC to pursue, it is expected that the further development of the concept and pursuit of proposals and commitments would be undertaken by the NYAC board, with an open invitation for participation by ASNY members and astronomers within NY.

A suitable strawman for a partnership in Gemini would be an equivalent value to the $10M/yr current UK contribution. Such a contribution would be comparable the University of California (UC) contribution to base budget operations of the Keck observatory, for which it receives approximately 40% of the time on the Keck telescopes. The UK share of Gemini nights is 22%. The relative costs based on these figures result in a cost per night roughly twice as much for Gemini, partly because the UC Keck support does not include instrumentation development, partly because the operations of Gemini are significantly more complicated as a result of operating telescopes at two sites in different countries and providing queue scheduled observation. Any new Gemini partner that offered to replace the UK financial contribution would presumably be expected to make whole an equivalent capital contribution to receive an equivalent share of 22% of the nights. NYAC could presumably argue that in effect the NY State astronomical community has already contributed as part of the US community. Ultimately, the details would be the subject of negotiation between the Gemini board, executive agency (currently NSF, but possibly subject to restructuring) and NYAC. Since consensus is that likely sources of funding would restricted to be spent within NY and it is likely that Gemini would discount in-kind contributions, it is premature to specify either the cost to NY or the return in nights. However, the appropriate ballpark numbers for consideration are $10M/yr and approximately 140 telescope-nights per year. It is worth noting that there are no clear breakpoints in the funding, and at lower levels it may well still be possible to negotiate a partnership.

It is unlikely federal sources would fund a proposal for privileged access to Gemini for NY State, but it is possible to imagine that incremental funding from federal sources might ultimately be forthcoming in support of instrumentation (e.g., TSIP) or large science programs (e.g., followup in support of NASA missions) if NY were to become a Gemini partner. It also does not appear likely that even a consortium of institutions would be able to muster sufficient resources without state funding. Through NYAC, an approach would be made to the state with a unified front to develop a center within NY to develop instrumentation and operations for Gemini. It would be highly desirable to solicit institutional commitments from partner institutions in the form of either ongoing budgets or overhead return. It may be possible to generate approximately $1M/yr for a cash contribution to Gemini that is not directly from state funds. Such commitments would provide a much stronger negotiating position for NYAC with the Gemini board.