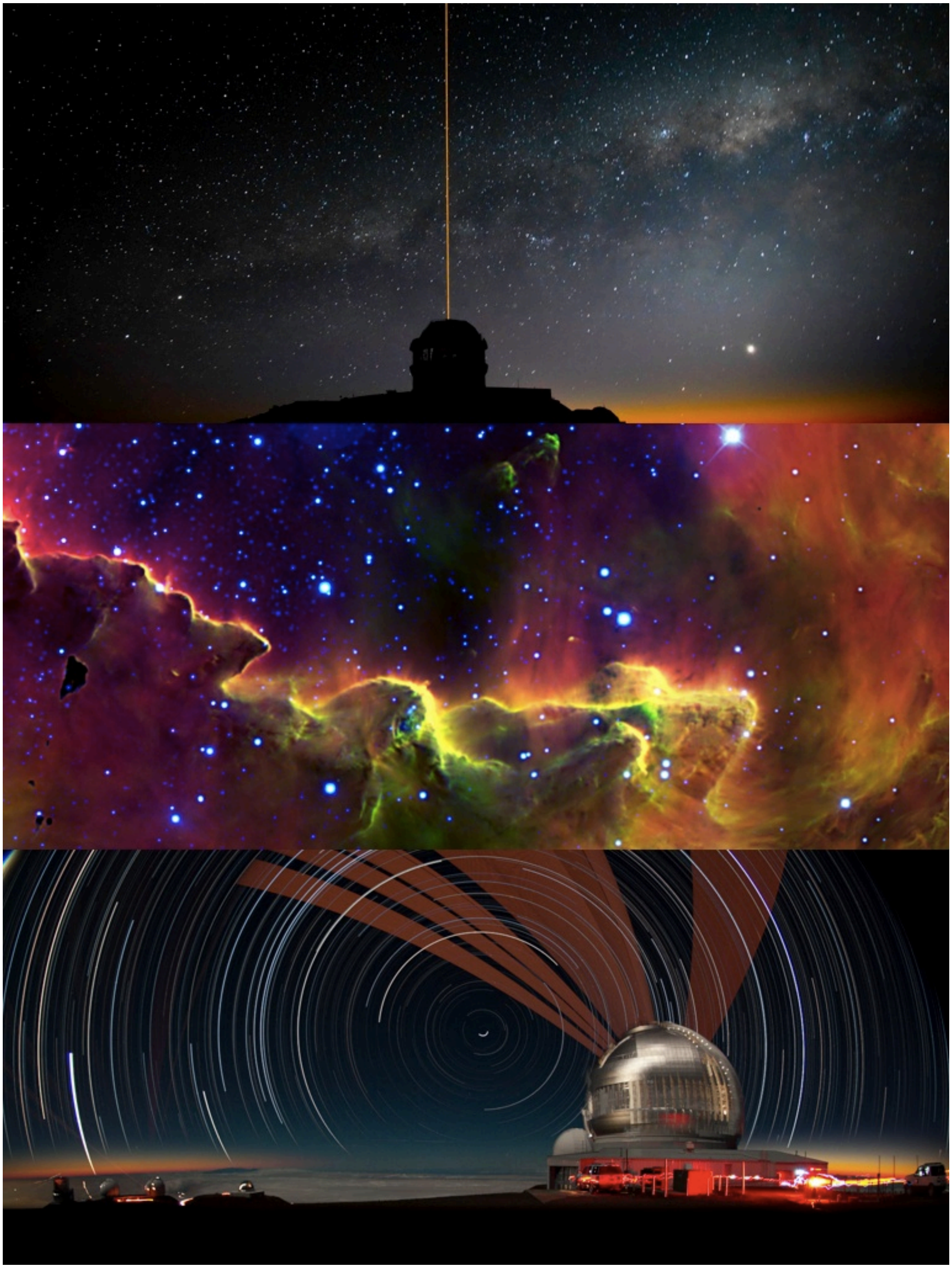
Gemini Observatory Vision
2012 and Beyond



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1. Executive Summary

1.1 Introduction

This document describes how the Gemini Observatory will help achieve the science of the Decadal Surveys over the next five years, and presents a vision of further development in the longer term. The near term is a time of great change for Gemini: budget contractions are driving a change in operations. This challenge nonetheless presents an opportunity to improve our efficiency while effectively pursuing our core mission: *To advance our knowledge of the Universe by providing the international Gemini Community with forefront access to the entire sky.*

1.2 The Gemini Observatory

The Gemini Observatory operates two 8-meter "twin" telescopes, one on Mauna Kea in Hawai'i and the other on Cerro Pachón in Chile, providing access to the skies of both hemispheres. Gemini is one of today's forefront astronomy research facilities, providing telescope and instrument systems with excellent performance through a broad range of capabilities in the optical and infrared spectrum. In addition to "classical" observing (principal investigators execute their own programs on fixed dates at Gemini), the observing model includes a multi-instrument "queue" system (users' observing requests are executed by Gemini staff). This approach has made Gemini one of the most effective target of opportunity observing systems available, both for fast-response targets (e.g., transients like gamma-ray bursts) and slow-response follow-up targets (e.g., distant supernovae).

The international Gemini Partnership governs the Observatory for the benefit of the user community. Withdrawal of the United Kingdom from the Partnership and the corresponding budget contraction are refocusing Gemini. One strength to cultivate is the international partnership; any new model for Gemini must retain the benefits of the Partnership. A second strength is the innovative instrumentation and operations capabilities of the Observatory. We are on the verge of transforming the instrument suite at Gemini South, introducing the unique capability of laser multi-conjugate adaptive optics (MCAO), along with multi-object near-infrared (NIR) spectroscopy and "extreme" high-contrast adaptive optics.

1.3 Gemini at the Scientific Frontiers

The pressing questions for the future of astronomy and planetary exploration were defined by the recent decadal surveys: *New Worlds, New Horizons in Astronomy and Astrophysics (NWNH)*, and *Visions and Voyages for Planetary Science in the Decade 2013-2022 (V&V)*. The capabilities of 8-meter class optical and infrared telescopes will be crucial as we attempt to answer them. Gemini has an essential role as the dominant public access to these facilities for the US astronomical community over the coming decade. In every research area noted in the surveys, spanning from the epoch of reionization to the nearby small bodies of our own Solar System, Gemini will provide leading and in many cases unique capabilities with which community scientists will make major advances. We give a small sample of areas in which the Gemini community will make significant contributions.

For the distant Universe, Gemini excels at NIR spectroscopy of faint objects, and can provide crucial evidence permitting us to quantify the epoch and process of reionization in the early Universe. The formation and evolution of cosmic structures will be probed by FLAMINGOS-2, whose wide field NIR imaging of "empty" fields will yield enough L* galaxies at $z > 7$ to trace the filamentary large-scale structure of the Universe. Transient phenomena, including gamma-ray bursts (GRBs), present some of the best opportunities to identify the most distant objects and probe the line of sight to them. Gemini's ability to conduct rapid follow-up observations of GRBs will continue over the next five years and beyond.

Within the galactic neighborhood, star formation histories of nearby galaxies can be gleaned from color-magnitude diagrams, with the NIR probing the cool stars of the red giant branch and asymptotic giant branch. Using adaptive optics, observations go beyond the Magellanic Clouds, to other members of the Local Group. The Gemini MCAO system literally expands the field of view for the required imaging.

In the realm of stars and stellar formation, the new Gemini high-resolution optical spectrographs to be offered in the near term will be used extensively. Some specific properties that must be determined are mass loss, rotation, and magnetic field. These measurements will answer fundamental questions about stellar evolution (how do rotation and magnetic fields affect stars? how do the lives of massive stars end?) which are ultimately connected to the lifecycles of galaxies, including the interplay of gas, metals, and energy they contain. Gemini will continue to observe the explosive end states of stars as supernovae. The crucial role for Gemini will continue to be follow up observations, especially spectroscopy, after discovery elsewhere. The existing capabilities (optical and infrared spectroscopy from both hemispheres) and observing modes (dominantly in queue, with rapid interruption possible) are vital.

Exoplanets will be a forte of Gemini in the coming years. The Gemini Planet Imager (GPI) will be a key new capability for further understanding the formation of stars and planetary systems, providing more complete characterization than any instrument today. GPI is an extreme adaptive optics (AO) system, providing contrasts of 10^{-7} over angular scales down to 0.2 arcseconds, probing separations as close as 3–5 AU in nearby systems. The primary science instrument is an integral field spectrograph, which will deliver 4000 spectra over the full field of view of 2.8 arcseconds and includes an optional polarimetric mode. The planned GPI science campaign will survey 600 nearby, young stars, and move beyond mere exoplanet census to actual population demographics. For each discovered planet (estimated to be around 50), GPI spectrophotometry will give effective temperature and luminosity. Careful astrometric measurements will also determine orbital motion and therefore semimajor axis. Eccentricity distribution of some of the population will also be possible, which will distinguish among various evolutionary states with high confidence, further testing models of formation and migration. Exoplanet spectroscopy with GPI will reveal atmospheric conditions and thermal history, thereby calibrating atmosphere and accretion models. In particular, multi-band and multi-epoch observations will test planet rotation timescales and rotational symmetry of planet atmospheres. The physical scale of the systems probed will be comparable to our own Solar System, providing effective comparisons with our local habitable zone.

Within our Solar System, Gemini observations have been used to determine mineralogy and grain size distribution on cometary nuclei, which can be related to their formation sites. For Kuiper Belt Objects (KBOs), Gemini observations have permitted characterization of the orbits of KBO binary systems, taking advantage of optimal seeing in the queue to obtain relative astrometry on scales of 0.02 arcseconds. These orbits ultimately constrain formation scenarios, and also provide relative system masses. Gemini provided crucial observations of Jupiter in the wake of repeated impacts in 2009 and 2010; the queue permitted extremely fast turn-around, capturing the rapidly fading heat from the massive explosions in the planet's atmosphere. Understanding the nature of these impacting bodies helps refine the populations of potential impactors, and resolve the "Friend or Foe" question: does Jupiter deflect these objects away from Earth or send them hurtling toward us.

A strong thread through many of the scientific questions that *NWNH* and *V&V* pose is the discovery potential of time-domain astronomy. Current and upcoming surveys, including Pan-STARRS, the Palomar Transient Factory, and LSST will provide many candidates of interest to a range of subjects. Gemini's operational strengths, including the queue and rapid response for targets of opportunity (ToOs), will be powerful tools to explore this realm.

1.4 Gemini Operations and Management

Gemini's unique niche is based on the combination of the telescopes, the instruments, and the operational modes. The telescopes' thermal infrared performance is outstanding, with emissivity of less than about 3%, the best of any ground-based facility. This performance is a result of protected silver coatings for all mirrors, using a formula developed at Gemini. The laser guide star facilities at both telescopes show continuous improvement. In the south, a new high-power (50 watt) laser provides a constellation of five guide stars for the AO system. Our queue mode has proved outstanding for rapid response observations.

The Observatory continuously tracks performance metrics for science output and operations. The number of refereed publications by users continues to grow, and the output is still accelerating as Gemini becomes a mature facility with a full instrument suite. The Gemini Science Archive functions as an effective mechanism to distribute data to program Principal Investigators within minutes of observation, and it allows further use of the data by the scientific public.

1.5 Gemini in the 2015 timeframe

The Gemini budget is experiencing a significant contraction. After careful consideration with all our stakeholders, we have made strategic choices that will preserve, within the planned budget envelope, the key functionality that our user community desires. We can fulfill the priorities the Gemini Board and the other stakeholders have set, outlined below, by building on existing strengths.

Deliver and operate high-quality instruments that represent the priorities of our community.
Instrument development and delivery is an ongoing process, and renewing capabilities is essential to remain competitive. We will reach some significant milestones soon, with the Florida Multi-Object Imaging Near-IR Grism Observation Spectrometer-2 (FLAMINGOS-2) as a facility instrument available for regular science use by the community in 2012, and the Gemini MCAO System (GeMS) with the Gemini South Adaptive Optics Imager (GSAOI) going through final commissioning and verification. We will maintain current capabilities, while improving them, as illustrated by the new detectors for both Gemini Multi-Object Spectrographs North and South (GMOS-N and GMOS-S). We will replace some of the existing suite with new instruments. Gemini is currently pursuing two separate options for high-resolution optical spectroscopy: the Gemini High-Resolution Optical Spectrometer will be a new "workhorse" instrument for a variety of science projects requiring R ~ 40,000; and an optical fiber feed system will provide remote access to the existing echelle spectrograph at the Canada France Hawaii Telescope (CFHT). The plans for the next generation of instruments are still under discussion. Some of the leading possibilities are: building a full-wavelength optical–NIR spectrograph; replacing or upgrading the AO-capable NIR imager at Gemini North; implementing a high-resolution NIR spectrograph; and developing a ground-layer adaptive optics system.

Provide a high fraction of queue operations with appropriate data quality control, data products, and completion fraction.
In Gemini's multi-instrument queue, the highest-ranked scientific programs have priority for completion, and all programs are executed in the conditions they require. The queue allows for instrument changes during the night to match the executed programs to the weather. Over the next two to three years, we will plan to reduce the human effort required to deliver queue observations by investing in better software tools to assist queue planning and to evaluate data quality. In addition, Gemini will continue to support classical observing according to user demand.

Remotely operate the telescopes.
In the short term, we plan to begin operating from the base facilities. Immediate cost savings from this mode come from reduced fees for mountain lodging and meals, transportation, and reduced travel. In addition, increased oxygen at the bases provides a better work environment. Increased and more regular measurements of all systems may even improve telescope and system reliability. Moreover, base facility operations are a natural step to truly remote observing, from the users' home countries.

Improve the interface with the partner community.

During this transition, open lines of communication are critical. Formal lines of communication have traditionally included the Board and the Gemini Science Committee (GSC), which acts as both a user committee and scientific strategic planning committee. We have reformed the GSC to explicitly address these dual functions separately, as a Gemini Observatory Science and Technology Advisory Committee (G-STAC) that focuses primarily on strategic instrumentation planning, and a separate Gemini Users' Committee. Informal lines of communication will continue to include participation in meetings and town halls both for science and for instrumentation, as well as continued hosting of visiting observers at the facilities. We will maintain the distributed support model that includes National Gemini Offices (NGOs). We will continue to improve communication with them, to develop tools to help them fulfill their support function efficiently, and to provide more opportunities for the NGOs to shape the operation of which they are a part.

Observatory operations are already being transformed in order to meet these goals within the finite (and declining) budget, leaving a more efficient observatory that is sustainable over the long term. The most significant spending cuts come from reduced staff size. Some of the labor loss is replaced with improved tools and increased efficiency. However, we will not deliver everything we had in the past. The most noticeable effects for users will be to offer only four instruments and laser AO at each site and to reduce the net research effort at Gemini. The margin to deal with unexpected events will be diminished, so delivered instruments must be high quality and robust.

1.6 Broader Impacts

Gemini's efforts to broaden participation of underrepresented groups start with its hiring practices, where the Observatory has the most control and the most direct influence. Currently 33% of Gemini's Ph.D. scientists are female, which is over twice the national pool average, with half of the tenured scientific staff (of four) female. Female representation in the engineering occupations presents the greatest challenge for Gemini; locating and hiring women in the engineering fields continues to be difficult. Gemini will continue to strive to improve gender balance in all areas.

Gemini has established excellent relationships with US electronic and print media and with science publications worldwide. The regular distribution of Gemini press releases to this network has resulted in the broad dissemination of news stories in local, regional, national print and electronic media, as well as numerous articles in popular science, technology, and educational publications. The Public Information and Outreach group coordinates Gemini's efforts to disseminate information broadly. They produce the GeminiFocus newsletter semi-annually and issue web features and press releases regularly. They also produce educational material for use throughout the partnership. Gemini is now developing new media contributions, including podcasts and Facebook participation.

Ongoing educational activities at both sites center on the local communities. These include FamilyAstro and interactive presentations with a portable planetarium, which reaches remote sites. Gemini leads the flagship Journey through the Universe program in Hawai'i, and has introduced a pilot version in Chile (in 2011), which will be developed in coming years. In total, these programs reach thousands of people at all levels annually. In addition to these activities, student internships and a well-developed staff mentoring program are key elements that promote teaching, training, and learning.

1.7 Observatory Management and Budget

The International Gemini Agreement governs all aspects of the Observatory, enabling the Gemini Observatory to serve the interests of all its member countries. The National Science Foundation (NSF) acts as the Executive Agent for the Gemini Board under the terms of the International Agreement. The NSF administers a Cooperative Agreement, with Association of Universities for Research in Astronomy (AURA) as the selected Managing Organization. Policy and financial decisions by the Gemini Board are executed by the NSF through this Cooperative Agreement. As the parent organization and legal entity, AURA manages the Gemini Observatory as a distinct operational unit. AURA is accountable to the Gemini Board, through the NSF, for operating the Observatory within specified parameters of performance, schedule, scope, and budget. The NSF provides the necessary authority to enable effective execution. In turn, AURA delegates authority to the Gemini Director and provides oversight in accordance with AURA policy through the AURA Oversight Council for Gemini (AOC-G).

1.8 Summary of Gemini in the Near Term

Gemini Observatory is an essential element of the astronomical capability of all its partners, including the US. Compelling science will continue to be done from the ground on 8-meter facilities, and community astronomers require access to pursue their own programs. Gemini's declining budget requires a transformation to more efficient operations, much leaner than recent decadal surveys had considered for the Observatory.

Despite the financial challenges, the core goals of the Observatory can be maintained and the Gemini Partnership's vision can be realized. The budget reduction primarily causes staff size reductions, which in turn means the margin available to respond to unexpected or unplanned problems will be reduced, with some risk to on-sky performance. Nevertheless, we will continue to deliver cutting-edge instrumentation to the Gemini community (limiting the suite on each telescope to four instruments + laser AO). We will maintain queue operation to use the available telescope time efficiently. The queue must execute with reduced human effort, hence short-term investments in software development are required. Base facility operations will promote more efficient observing, and it offers an opportunity for later expansion to truly remote use of Gemini. The Observatory will improve interactions with the US and international user community: directly, through the NGOs, and with formal structures that address both strategic and immediate needs.

The end-state of Gemini Observatory by 2015 represents a long-term balance between funding resources and operational needs, provides the partner astronomical communities with world-class 8-meter facilities, and renews our focus on the user needs.

1.9 Strategic Vision for the Long Term

At Gemini, we believe that the future of astronomy relies critically upon international collaboration. With sites in Hawai‘i and Chile, a highly international heritage, and world-class capabilities, Gemini is uniquely poised to take a leadership role in nurturing inter-observatory collaborations that could transform the way ground based astronomy is conducted in the future. We envision the Gemini Observatory in the future as a cornerstone of a broad network of telescopes encircling and embedded in the Pacific Ocean. This "Pacific Observatory Network" has the potential to link individual autonomous telescopes into a confederation of facilities working jointly.

In the north, the Mauna Kea observatories comprise the largest collection of astronomical light gathering power on earth. Gemini North has used this to advantage. Our time-exchange programs are already nearly a decade old, and have been a success, with oversubscription levels from Gemini and Subaru approaching 5 or 6. The program is poised to expand considerably in the future. Beyond time exchange, pathfinders in inter-observatory development programs also exist across the Mauna Kea observatories. For example, the GRACES project, which is underway now, is designed to fiber feed the CFHT high resolution optical spectrometer ESPaDOnS from Gemini-North. Another area in which the Mauna Kea observatories have excelled is in laser adaptive optics, and future cooperative developments can broadly serve the scientific stakeholders. With 4 laser AO systems in operation today, no other collection of diverse telescopes in the world approaches the depth and breadth of adaptive optics capability now in Hawai‘i. Next-generation AO systems currently under consideration include a high order laser tomographic system at Keck that can operate at visible wavelengths, Ground Layer AO systems at Gemini-North and Subaru, and an extreme wide field (1 deg) NGS Ground Layer AO system at CFHT. These systems are all in the formative stages of development; the ground for future collaborative development remains fertile.

In the south, Gemini continues to offer unique capabilities like MCAO, supported by new (likely spectroscopic) instruments. Nearby, ALMA will require supporting observations at optical and IR wavelengths. The link to Cerro Pachón would also include LSST, which can provide a steady stream of targets requiring rapid follow-up, one of Gemini's key strengths.

The future of Gemini must be put in the context of a world that includes the James Webb Space Telescope (JWST) and Extremely Large Telescopes (ELTs). The capabilities of these new facilities will surpass existing 8–10m telescopes many areas. Nonetheless, Gemini will still have important roles. Some examples include extremely high-resolution spectroscopy, and very rapid response for ToO observations. Gemini could provide complementary observations for JWST or ELTs, e.g., for target selection via a broad survey, or at multiple wavelengths or at optical wavelengths. Along the path toward these new facilities, Gemini offers important technical lessons. In particular, the ELTs will require multi-guide-star AO, for which GeMS is a pathfinder.

Nearly 20 years ago, AURA—with the NSF—was instrumental in assembling an international group of astronomers and technologists who believed that they could build a unique, powerful, ground-based observatory with two telescopes, one in the Northern Hemisphere and the other located in the Southern Hemisphere. Each telescope's clarity of vision would rival that of the Hubble Space Telescope (HST), with a vast single-piece mirror having at least four times the collecting area of then existing telescopes. Gemini Observatory today is the realization of that effort. As we move forward with our transition plan, the strengths and unique capabilities of the Gemini Observatory are foremost in our strategic choices. As NSF ponders the future and the strategic choices it must make, we note that the Gemini Observatory fulfills a critical role in the landscape of astronomical tools. We urge the NSF to retain the funding for this facility, and put us on the path to a vibrant future in astrophysical research.

2. Introduction

The Gemini Observatory is a forefront astronomy research facility. After transitioning from the energy and anticipation of the construction period to ongoing operations over the past decade, we now strive to achieve long-term sustainability, while also maintaining our competitive advantage, within a constrained budget. In the future, we will capitalize on the unique strengths built into the Gemini telescopes, leverage synergies with other facilities, and allocate our finite resources to maximize the quality and quantity of our scientific product.

Gemini's budget challenge (with the withdrawal of a 25% partner at the end of 2012) is not unique in the current global economic environment, and we have critically examined all aspects of operating Gemini as we seek to maximize research functionality to support our US and international community. While these budget reductions will result in some loss of capability and service to the scientific community, we aim to retain fundamental functions. The core requirements that determine the path forward, established by the international stakeholders and the Gemini Board, are:

1. To deliver and operate high-quality instruments that represent the priorities of our community;
2. To provide a high fraction of queue operations with appropriate data quality control, data products, and completion fraction;
3. To have the ability to remotely operate the telescopes; and
4. To better interface with our partner communities.

While seeking to fulfill these goals, we will take advantage of and develop our existing strengths, which include the international partnership. The partners bring diverse benefits and perspectives to the Observatory and enhance its scientific results. As operations and instrumentation become more complex, and the research questions more profound, international collaboration provides effective solutions. Any new model for Gemini must retain the benefits of the international partnership. A second strength is the innovative instrumentation and operations capabilities of the Observatory. Merely supporting technical capabilities and operations as they currently exist with no further development would result in a facility that falls behind its competitors.

Within this framework, we present a plan that enables Gemini Observatory to remain a world-class international facility, operating telescopes in both the Northern and Southern Hemispheres. The transition to new operations requires short-term investments, which will provide for long-term sustainability under a reduced recurring budget in the future. A central element of this future includes developing advanced new instrumentation to meet the needs of Gemini's diverse and demanding community. Technology both enables and limits our discovery horizon in astronomy. National facilities like Gemini must strive to achieve a balance to ensure that a baseline of competitive instruments is always available, while pushing research and technical frontiers. This balance is never easy to achieve, but is essential for the long-term vitality and sustainability of Gemini, and it is reflected in the blend of instruments now offered and planned for development. While the exact details of the next generation of instruments are still evolving, what is clear is that we will provide our community with a combination of advanced laser-based adaptive optics systems and "workhorse" instruments, capable of effectively supporting a wide range of optical, near-, and mid-infrared programs, which is consistent with meeting the needs of a very diverse international user community.

Queue observing has proven to make efficient use of the Gemini telescopes to deliver scientifically useful data. We have evaluated the existing queue-based science operations in detail and identified its truly essential components, which are incorporated in this plan. We will leverage existing investments and with additional development, reduce the net human effort of running non-classical observing modes. The key objective is to reduce the burden not only on staff, but on all users as they develop and execute their observing programs.

We propose to establish base facility observing and move toward a remote telescope operations model. The advantages of this model, including long-term cost savings, are significant. The period of the transition presents a unique opportunity to introduce this modern and improved approach. We expect base facility observing to be a useful segue into more remote observing, such as from the partnership home countries.

The changes to improve interactions with the partner communities are more subtle, but they represent a crucial shift of attention throughout Gemini. While the National Gemini Offices will remain as a key interface between their local communities and the Observatory, the Observatory must directly engage with the scientific and technical members of the partnership and respond to their needs, considering both strategic goals and shorter-term interests. Greater visibility and communication between the Observatory's managing leadership and the partner communities is an important element of this plan, which continuing scientific and technical interaction further support. Restructuring scientific and user advisory committees will improve the partners' communication pathways.

Essential to all of this activity will be the maturing of Gemini's internal planning system that links and coordinates activity observatory-wide, promotes a working culture of open communication and accountability, and enables the wise allocation of resources to achieve our objectives. These signs of growth and evolution are all manifestations of a maturing observatory, rightfully taking its place alongside contemporary facilities that collectively serve as our primary portals on the Universe.

Gemini has been a powerful tool for astronomical research over the past decade. Concentrating on our core mission, our plans for the coming decade will ensure that Gemini stays in the forefront of research for the astronomical community. Equally important is the immense value of Gemini's ability to educate and inspire the public at large, young and old, most of whom have never experienced first-hand what a telescope can reveal about the Universe.

In the pages that follow, performance metrics, budget details, and publication statistics are described, quantifying the current and proposed future capabilities of the Gemini Observatory. While important to gauge the technical progress and scientific promise of Gemini, these metrics should never be confused with *why* Gemini is important. That is a completely different matter, which grounds our mission and guides our purpose: *Exploring the Universe, Sharing its Wonders*.

2.1 Observatory Vitals and Key Strengths

Many entities compose Gemini Observatory, from the international partner agencies that created and sustain it, to the people that operate it, to the technology that enables it, to the research community that harnesses it. Here we describe the basic ingredients of Gemini and what distinguishes this observatory from many others.

2.1.1 The Gemini Partnership

Nearly 20 years ago, AURA—with the NSF—was instrumental in assembling an international group of astronomers and technologists who believed that they could build a unique, powerful, ground-based observatory with two telescopes, one in the Northern Hemisphere and the other located in the Southern Hemisphere. Each telescope's clarity of vision would rival that of the Hubble Space Telescope (HST), with a vast single-piece mirror having at least four times the collecting area of then existing telescopes.

As a result of these efforts, in 1993 the United States, United Kingdom, Canada, Chile, Argentina, and Brazil came together to form the government-to-government Gemini Partnership. The current partners are the United States, the United Kingdom, Canada, Australia, Brazil, and Argentina[1]. Table 2-1 shows the national astronomy-research-funding agencies that compose the international Partnership under the International Gemini Agreement. They are listed in the order of their respective partnership shares.

Country	National Agency
United States	National Science Foundation (NSF)
United Kingdom	Science and Technology Facilities Council (STFC)
Canada	National Research Council (NRC-CRNC)
Australia	Australian Research Council (ARC)
Brazil	Ministério da Ciência e Tecnologia e Inovação (MCTI)
Argentina	Ministerio de Ciencia, Technología e Innovación Productivia (MCTIP)

Table 2-1: Current Gemini Partner Agencies

2.1.2 Twin 8 m Telescopes

Each of Gemini's two telescopes has a high-quality, 8-meter monolithic primary mirror. These highly automated telescopes incorporate active and adaptive optics to produce very high-resolution systems. Moreover, they take advantage of two of the highest-quality established observing sites on the planet and collectively provide full coverage of both the Northern and Southern skies. Gemini's most widely known distinction among other 8–10 m class observatories is its highly optimized infrared (IR) design. The telescopes employ unique sputtered multi-layered silver coatings on their primary, secondary, and tertiary mirrors that, together with other facets of their design, achieve extremely low emissivity, diffraction-limited performance at near-infrared (NIR) and mid-infrared (MIR) wavelengths, and smooth stable point-spread functions. This performance combination renders Gemini the world's most sensitive ground-based telescopes at MIR wavelengths.

The Gemini North telescope is one of the four largest optical/infrared telescopes that stand in the summit region of Mauna Kea about 4175 m (13,700 ft) above sea level on the Big Island of Hawai‘i. Mauna Kea's summit is acclaimed as the Northern Hemisphere's premier observing site, being surrounded by a thermally-stable tropical sea, bathed in dry trade winds above the inversion layer, atop a massive mountain with very gradual slopes, and devoid of major sources of light pollution. In the south, sharing much of the common infrastructure with the other AURA-managed facilities on Cerro Pachón and nearby Cerro Tololo, the Gemini South telescope stands on a ridge in the Andes at 2743 m (9000 ft) elevation on Cerro Pachón. Located some 300 m from the 4 m SOAR telescope, Gemini South's location has proven to be one of the best-developed observing sites in the Southern Hemisphere.

Each telescope feeds a modern suite of imagers and spectrometers, which collectively provide the Gemini community with access to the optical, near-infrared, and mid-infrared ground-accessible spectral windows. Each telescope nominally mounts three instruments concurrently, plus an adaptive optics (AO) system that can feed any instrument, and a calibration system, all on a Cassegrain turret. Redirecting the beam with a movable mirror allows almost instantaneous instrument changes and on-the-fly responses to changing sky or instrument conditions, or time-critical observations. The instruments are normally mounted for periods of many months, which avoids lost observing time and cost due to frequent remounting. Gemini is currently able to maintain five instruments in total (including those that are off the telescope) in addition to AO capability and calibration at each site. The instruments are highly integrated into Gemini's control systems and facilitate queue as well as classical observing.

Gemini's Hilo Base Facility (HBF) is located on the University of Hawai‘i-Hilo campus. It is the headquarters for the Gemini directorate and the administrative core for Gemini North. The facility

[1] Australia joined the Partnership in 2000. In 2003, Chile reduced its participation to that of an observing-site host.

provides office and lab space for science, engineering, and administrative staff, and supports data processing and other operations needs. Like its counterpart in Hilo, the Gemini South Base Facility (SBF) overlooks the Pacific Ocean but from La Serena, Chile. The SBF provides office, lab, and meeting space for science, engineering, and administrative staff, network and data-processing equipment, and a remote operations room. It is located within the same gated compound as the operations bases for the AURA-operated Cerro Tololo Inter-American Observatory (CTIO) and Southern Astrophysical Research telescope (SOAR).

2.1.3 Science Operations – Optimizing Scientific Return

Time on the Gemini telescopes is awarded to each of the partner's national communities in proportion to the partner's financial contribution to capital investments and operating costs of the Observatory. Each partner has its own National Gemini Office (NGO), which acts as the interface between the local community and the international Gemini Observatory. The NGOs interact with the Observatory on many levels. These include managing a National Time Allocation Committee (NTAC) in each respective country. The NTACs collect the observing proposals from their respective constituents each semester and conduct peer reviews to evaluate and prioritize them.

The results of all of the NTAC deliberations are then forwarded to the International Time Allocation Committee (ITAC), composed of representatives of the national partners and the Observatory staff. The ITAC merges all of the national evaluations and reaches a consensus prioritization of the entire set. The result is the grouping of all the proposals into three broad scientifically prioritized sets, referred to as Bands 1, 2 and 3, where Band 1 is the highest-priority set and Band 3 is the lowest. The Observatory then devises a plan to schedule the Bands within the overarching national allocations. Given the size of Gemini's community and total time available, this process by design results in an oversubscription of observing time. The Observatory's challenge, then, is to obtain high-quality data for as many programs as possible, ranked by Band, in each given semester.

For US astronomers, Gemini plays a critical role, as the primary 8 m telescope facility to which the entire scientific community has access. The substantial amount of time that is available, the consistency and longevity of that access, and the community participation in the Observatory development plans all reinforce Gemini's significance. As a result, Gemini is one of the leading facilities that individual investigators whom the NSF funds propose to use in their research programs. In return, supporting a diverse scientific community, many of whom will not regularly obtain large amounts of time individually, demands a high level of support by the Observatory. Gemini takes this role seriously, consistent with our primary mission to enable the scientific goals of partner astronomers. We provide a high level of service to support broad access, including user support for observation preparation and execution, data reduction and analysis tools, and a helpdesk open to answer additional questions. After a proprietary period, all data and the associated calibrations that are essential to make use of them are publicly available for use by other researchers through the Gemini Science Archive.

2.1.4 Classical and Queue-Based Operations

In seeking to optimize the scientific return on investments made, Gemini offers both queue and classical observing modes. Gemini's rapidly reconfigurable multi-instrument system is the efficient and effective operational backbone behind Gemini's queue mode: the scientific ranking of a program determines its priority for execution, and each is completed under the sky conditions it requires. Queue-based operations rely upon the Observatory staff conducting researchers' observations by executing preprogrammed scripts that are designed by the researcher; these scripts define how a program should be carried out. When appropriate to the study in question, a queue-based model makes more efficient use of highly oversubscribed observing time (e.g., best seeing conditions or relatively rare low water vapor conditions). Observations and calibrations can be more optimally utilized across multiple programs, enhancing the science productivity of the Observatory on behalf of the entire Partnership.

Classical observing—hands-on observing by a Principal Investigator (PI) team using a fixed block of time—can also be valuable. Advantages of classical operations include programs that involve new, experimental observing procedures, the training of young scientists, technology explorations, and

Gemini North			Gemini South		
Instrument	**Description**	**Band**	**Instrument**	**Description**	**Band**
GMOS-North	Multi-object imager and spectrograph R~5000, hundreds of objects at a time	Optical	GMOS-South	Multi-object imager and spectrograph R~5000, hundreds of objects at a time	Optical
NIRI	Imager	Near-IR	FLAMINGOS-2	Imager and multi-object spectrograph ~80 spectra at a time	Near-IR
GNIRS	Long-slit, cross-dispersed spectrograph; 5000≤R≤18000	Near-IR	NICI	Dual-channel coronagraphic imager Internal 85-element AO	Near-IR
NIFS	Integral-field spectrograph R~5000 Has coronagraphic mode	Near-IR	GSAOI	AO imager, for use with GeMS Rapid tip-tilt on readout	Near-IR
Michelle	Imaging spectrometer; longslit R~5000; cross-dispersed R~30000	MID-IR	T-ReCS	Imager and spectrograph 100≤R≤1000	Mid-IR
ALTAIR	Facility AO system Single natural or laser guide star	Near-IR	GeMS	Facility multi-conjugate AO system Five laser guide star constellation	Near-IR
Notes: Mid-IR instruments are diffraction limited in natural seeing. Near-IR instruments are diffraction limited with AO.					

Table 2-2: Gemini instruments and facility systems.

instrument commissioning. Moreover, these programs are extremely useful for maintaining direct contact with the community and for the community to remain familiar with the Observatory and its staff. Gemini supports classical observing in response to demand, currently around 10% of available time.

2.1.5 Instrumentation

Gemini offers a range of imagers and spectrometers for observations at optical through MIR wavelengths, and adaptive optics at both sites. A summary of current capabilities, including those for which commissioning is in progress, is listed in Table 2-2. Several instrument and facility projects are nearing completion, which will provide new opportunities for the science community over the next year, and the results of other work in progress will become available later.

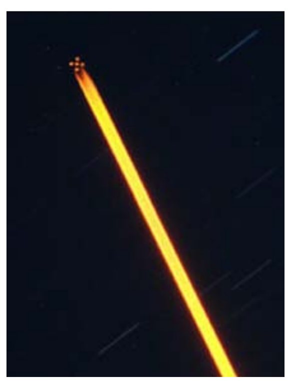


Figure 2-1: (left) Propagation of the Gemini South laser. (right) The 5-star constellation during technical commissioning.

Gemini Multi-Conjugate Adaptive Optics System (GeMS)

The Gemini South multi-conjugate adaptive optics facility is Gemini's next generation AO system. It is currently the largest internal development project at Gemini, and it is being commissioned at Gemini South. It will provide a *unique* science capability, delivering near-uniform and excellent image quality over the full 85 arcsecond square field of view, using the Gemini South Adaptive Optics Imager (GSAOI) as the science instrument.

The GeMS laser first light on the sky was achieved on January 21, 2011 (Figure 2-1). Technical commissioning of the system continued through the first half of the year, achieving first engineering light with GSAOI on April 19, 2011, and first science commissioning light on December 15, 2011 (Figure 2-2). The uniformity of the point spread function is excellent, with FWHM = 0.080 +/- 0.002 arcseconds measured from 350 stars over the full field of view in stacked images. Individual frames show FWHM at the diffraction limit and Strehl ratios in *H* band of 35%. System Verification is expected in the first half of 2012.

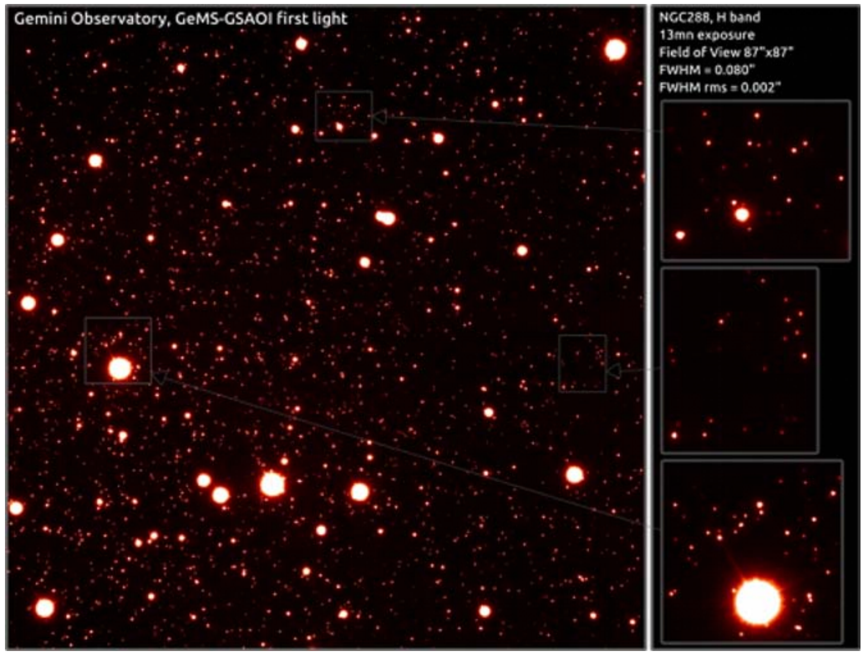


Figure 2-2: First light image from GeMS, NGC 288 in *H* band.

FLAMINGOS-2

FLAMINGOS-2 is a near-infrared wide-field imager and multi-object spectrometer. It was constructed by the University of Florida Astronomy Department and delivered to Gemini South in July 2009. Although it was installed on the telescope and achieved first light during on-sky acceptance testing in September 2009, Gemini took responsibility for the instrument to perform the significant work required to release it to the community as a facility-class instrument. Key areas of attention were thermal and vacuum stability, mechanism reliability, installation of the R~3000 grism, documentation, and replacement of the science detector. Improvements have been made successfully in all these areas, with initial recommissioning begun in December 2011 (Figure 2-3). System Verification is expected in early 2012, with regular science use by the community in queue and classical modes during semester 2012B.

Gemini Planet Imager (GPI)

GPI is an extreme AO imaging polarimeter and integral field spectrometer, which will provide diffraction-limited data from 0.9 to 2.4 microns. The system will provide contrast ratios of 10^{-7} on companions at separations 0.2-1 arcseconds in observations of 1-2 hours. The science instrument will provide spectroscopy or dual-beam polarimetry of any object in the 3 arcsecond field of view. GPI is being built by a consortium of US and Canadian institutions, led by Brice Macintosh of Lawrence Livermore National Laboratory and is expected to be delivered to Gemini South at the end of 2012.

GMOS CCD upgrade

In addition to new instrumentation, Gemini is delivering improved capabilities through upgrades to existing instruments. The GMOS-N CCDs have been replaced with a more red sensitive set made by e2v. Over the next year, both the GMOS-N and GMOS-S detectors will be replaced by even more sensitive devices (fully depleted CCDs sensitive to 1 μm) made by Hamamatsu Photonics.

Figure 2-3: FLAMINGOS-2 observation of NGC 2442; color composite from *J*, *H*, and *K* bands.

Future Developments – Optical Spectroscopy
In response to community demand, Gemini is pursuing development of two capabilities for high-resolution optical spectroscopy. The Gemini High-Resolution Optical Spectrometer (GHOS) will nominally provide R ~ 40,000 simultaneous coverage over wavelengths from 370 to 1000 nm. The science cases for GHOS could be met by a range of technical solutions. Currently three conceptual design studies are in progress, which may result in either a Cassegrain-mounted or fiber-fed instrument, and may also provide additional capabilities such as multiplexing. If all cost, schedule, and capability requirements can be met, GHOS will be delivered around 2015.

Gemini is also pursuing use of the existing ESPaDOnS spectrograph at the Canada-France-Hawaii Telescope (CFHT): Gemini Remote Access to CFHT ESPaDOnS (GRACES). GRACES will provide spectral coverage from 400 to 1000 nm and R ~ 60,000. The fiber input will be via GMOS-N, using a conduit between the telescopes that already exists to convey the 270-m fiber. The initial feasibility studies show competitive performance, especially at red wavelengths. CFHT is leading a design study, and if successful, science use of GRACES would be introduced in stages beginning at the end of 2012.

2.2 Overview of this Document

In Section 3 we assess future scientific trends that are grounded in research being conducted today and take advantage of some of Gemini's unique capabilities. Gemini will continue to play a vital role in making progress in these areas of interest that have been identified by recent decadal surveys in astronomy and astrophysics and planetary science. As an example, Figure 2-4 illustrates several such research topics that take advantage of Gemini as a high-resolution infrared-optimized platform that is capable of being reconfigured and pointed toward targets of opportunity (ToOs) with exceptional speed and efficiency. This type of rapid response capability is substantially rooted in Gemini being originally designed to switch *on the fly* to optimally match programs in the queue with changing weather conditions. In practice, these design features also have left Gemini with a unique capability, and obvious synergies with present and future synoptic survey facilities like the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS), the Visible and Infrared Survey Telescope for Astronomy (VISTA), and the Large Synoptic Survey Telescope (LSST).

The other area of future research that Figure 2-4 portends is in the field of exoplanets. In the span of about six months, research conducted at Gemini led to the announcement of the first exoplanet orbiting a star of similar mass to our own Sun, including spectra of the planet (Figure 2-4, center) and then, even more importantly, a trio of exoplanets orbiting a nearby star (HR8799; Figure 2-4, bottom).

Section 4 describes past work, to illustrate normal operations. We summarize operating metrics, including publications, queue completion rates, open-shutter efficiency, and delivered science time. Data and archiving systems and developments of the telescopes and their adaptive optics systems are also noted.

The bulk of the future plan over the next five years appears in Section 5. A key component of future development is the instrument complement. Gemini is currently engaged with the Science and

Technology Advisory Committee (STAC) and the national communities to determine the suite that best meets their needs. We present several possible new instruments that are *representative* of the types likely to be pursued. Changes in the operations model required to meet the budget target given by the Gemini Board are explained.

The broader impacts of this work, as outlined in Section 6, reflect the commitment Gemini has made to ensuring that the Observatory effectively engages our diverse community through our hiring practices, outreach programs, and science programs. Diversity at Gemini is an integral part of who we are. The locations of the Gemini base facilities lend naturally to a diverse staff, and Gemini's core commitment to diversity runs much deeper than the more than 20 nationalities represented on the staff.

Section 7 briefly describes the management structure of Gemini and the budget assumptions. The internal organization of the Observatory has recently been restructured. The international community of stakeholders remains linked to Gemini through a variety of oversight and advisory committees. The partner contributions and projected spending across various cost categories are explained here.

Section 8 summarizes the five-year program, and a model for the strategic vision appears in Section 9. While the longer-term future is more difficult to predict, the existing foundation leaves Gemini poised to lead a Pacific-wide network of astronomical observatories for the benefit of all their constituent scientists.

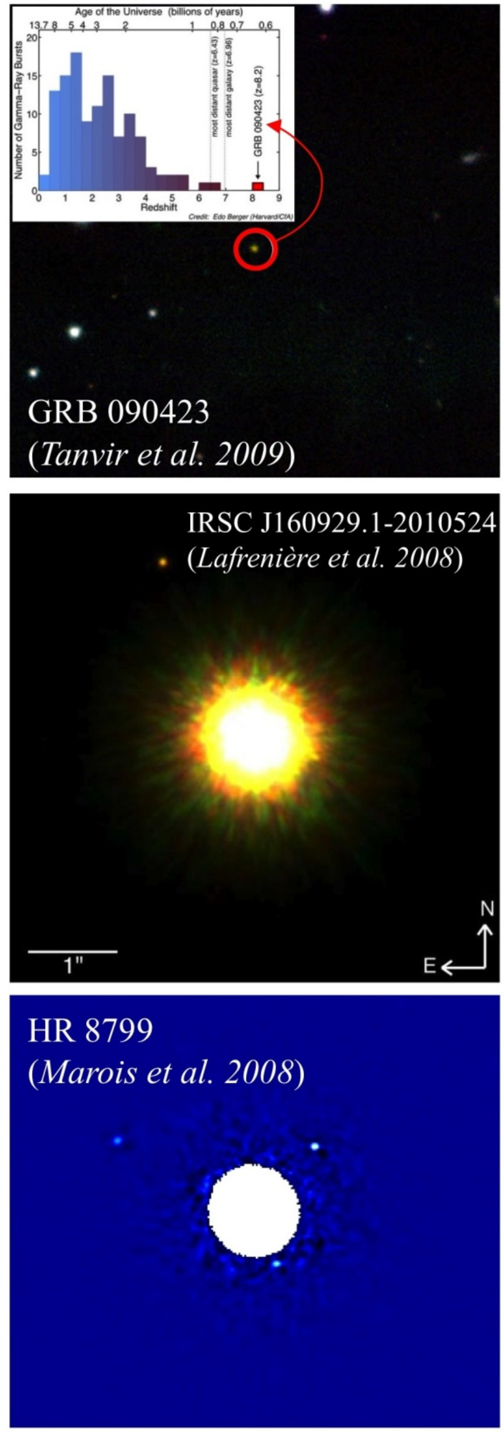


Figure 2-4: Trends in future research conducted at Gemini can be extrapolated from recent results that leverage Gemini as a nimble high-resolution platform for conducting infrared observations of faint or distant objects. (Credits: Tanvir et al. 2009 Nature 461 1254; Lafrenière et al. 2008 ApJ 689 L 153; Marois et al. 2008 Science 322 1348.)

3. Scientific Frontiers

Gemini is a flexible, general-use facility. The Observatory does not design specific experiments to answer particular scientific questions, but rather offers a range of capabilities that the scientists in the partner communities can utilize to pursue their own aims. We fully expect the current and upcoming capabilities of Gemini, considering both instrumentation and observing modes, to be employed to answer some of the pressing questions defined by the recent decadal surveys—*New Worlds, New Horizons in Astronomy and Astrophysics (NWNH)*, and *Visions and Voyages for Planetary Science in the Decade 2013-2022 (VV)*. Here we describe some of the specific areas where Gemini offers or will soon provide distinct or even unique advantages for astronomers in this context. Recent results indicate the kind of studies that will continue in the near term, and these will be enhanced in many cases as new capabilities come on-line. (Sections 4 and 5 provide more detail about the current and near-term operational and instrument capabilities that are noted here.) The topics are identified by the labels of the Science Frontier Panels of *NWNH* and as "Key Questions" in *VV*, and we concentrate on those where the impact using Gemini will be greatest.

3.1 Galaxies Across Cosmic Time

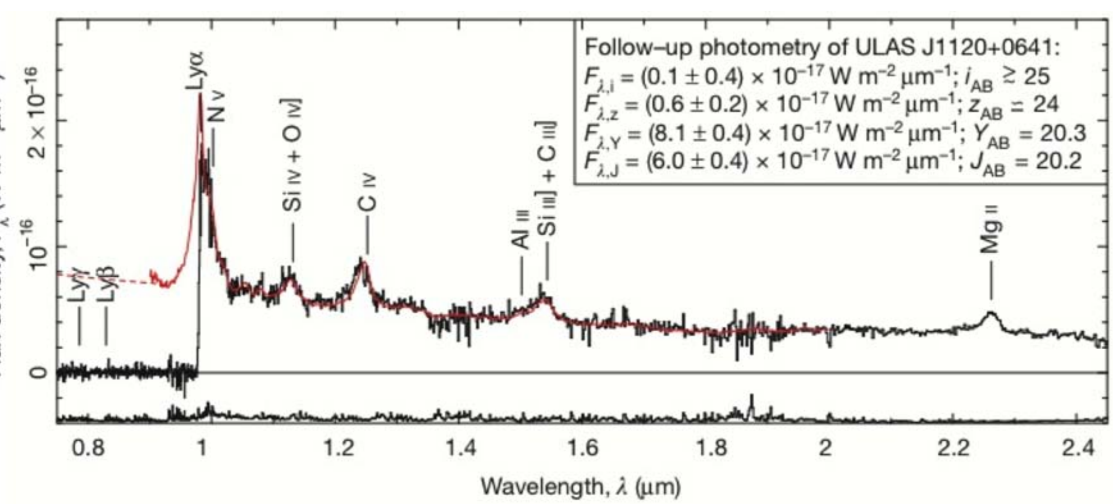


Figure 3-1: Spectrum of a z = 7.1 quasar (black), using GNIRS longward of 1.005μm. The red line shows a composite spectrum of lower-redshift quasars. (Credit: Mortlock et al. 2011 Nature 474 616)

Discovery Potential: Reionization
Quantifying the epoch and process of reionization in the early Universe is an underlying theme in the area Galaxies Across Cosmic Time. Observations of the redshift evolution of Lyman α emission is currently the only way to constrain the process of reionization between redshifts of z~6 (where populations of quasars and galaxies are observed) and z~1000 (which the Wilkinson Microwave Anisotropy Probe) maps. NIR spectroscopy of faint objects, at which Gemini excels, will provide crucial evidence. Current sensitive observations with GNIRS of a z=7.1 quasar, for example (Figure 3-1) indicate differences in the near-field ionization compared with lower-redshift samples. These accreting sources are rare, but additional candidates can be observed with Gemini. Lyman α is also the key tracer of gas inflow and outflow at high redshift, and it is accessible from Gemini, for redshifts 6-10, to study the cycle of baryons (Galaxies Across Cosmic Time Question 2; GCT 2).

How do cosmic structures form and evolve? (GCT 1)
FLAMINGOS-2 will open new possibilities, with relatively wide field NIR imaging of "empty" fields

yielding L* galaxies at z > 7. These samples are predicted to be sufficiently numerous to trace the filamentary large-scale structure of the Universe, and beyond mere detection, Gemini will be able to measure continuum luminosities and colors in images.

NIR surveys using large-aperture telescopes will be crucial to probe moderate redshift ($z \sim 1$–3) galaxy correlations, to learn how galaxies assembled. Spatially resolved spectroscopy of significant samples is an obvious and necessary step forward. Optical and NIR spectroscopy, especially taking advantage of multiplexing with both FLAMINGOS-2 and GMOS, will be essential to complement dedicated studies of baryonic acoustic oscillations on smaller telescopes, which will probe only lower redshifts.

What were the first objects to light up the Universe, and when did they do it? (GCT 4)
In addition to the persistent cases, such as the z=7.1 quasar, which shows a massive ($M_{BH} = 2 \times 10^9\ M_{Sun}$) black hole when the Universe was only 770 Myr old, transient phenomena, including gamma-ray bursts (GRBs), present some of the best opportunities to identify the most distant objects and probe the line of sight to them. Gemini's ability to reach ToO's rapidly and with sensitivity will continue over the next five years and beyond. The photometric z=9.4 GRB 090429B (Cucchiara et al. 2011 ApJ 736 7) based on NIRI data offers an example, with only poor weather preventing spectroscopic confirmation using GNIRS at the time of discovery.

How do black holes grow, radiate, and influence their surroundings? (GCT 3)
Measuring the masses of the central supermassive black holes of quiescent and active galaxies is one approach to answering this question. High spatial resolution observations isolate the black hole sphere of influence from its surroundings, as recent results using NIFS with laser guide star AO demonstrate. This work is especially effective when combined with additional observations on larger scales to measure galaxy-wide properties (e.g., Gebhardt et al. 2011 ApJ 729 119). The GMOS IFU has proven valuable for similar work, and when queue-scheduled can deliver optimal resolution (on 0.4" scales). The intriguing new result is that the most massive galaxies appear to fall above the standard "M-σ" relation of black hole mass and velocity dispersion, having higher black hole masses (McConnell et al. 2011 Nature 480 215). Further efforts to answer this fundamental question will continue to probe the most massive end of the relation, which requires going to greater distance.

How do baryons cycle in and out of galaxies, and what do they do while they are there? (GCT 2)
The cycle of star formation, energy exchange, and return of metals to the interstellar and intergalactic medium is not understood well. High spatial resolution observations using integral field units, especially in the NIR (e.g., NIFS) can reveal the outflow and inflow of gas at z>1. Some kinematic measurements have already been made from Gemini (Alexander et al. 2010 MNRAS 402 2211), showing that at the epoch of star formation ($z \sim 2$), the outflow energy is vast, greater than the binding energy of the host

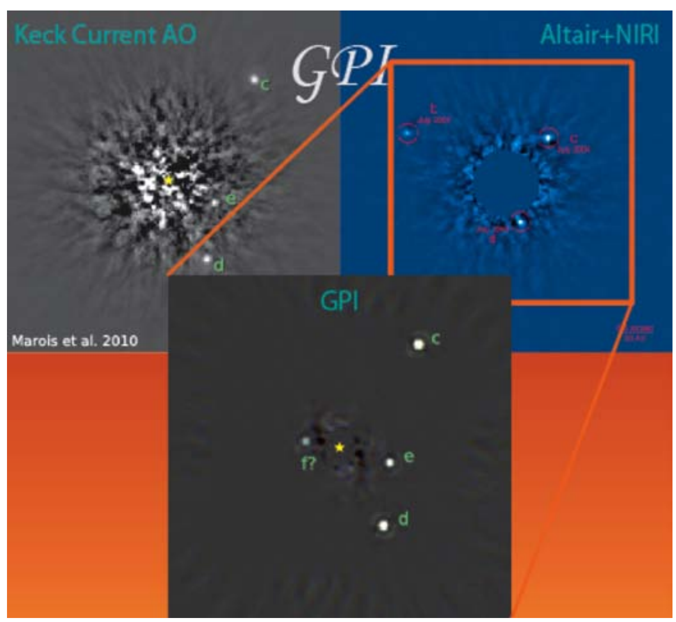


Figure 3-2: Simulation of a GPI observation of the HR8799 planetary family (cf Figure 2-4) including an additional 5 $M_{Jupiter}$ planet ("f?"). (Credits: simulation–C. Marois and M. Perrin; data–Marois et al. 2010 Nature 468 1080 and Marois et al. 2008 Science 322 1348.)

spheroid.

3.2 Planetary Systems and Star Formation

The Gemini Planet Imager (GPI) will be a key new capability for further understanding the formation of stars and planetary systems, and it will be used to move beyond mere identification of systems to their more complete characterization. GPI is an extreme AO system, providing contrasts of 10^{-7} over angular scales down to 0.2 arcseconds, probing separations as close as 3–5 AU in nearby systems (Figure 3-2). The primary science instrument is an integral field spectrograph, which will deliver 4000 spectra over the full field of view of 2.8 arcseconds and includes an optional polarimetric mode.

How do circumstellar disks evolve and form planetary systems? (PSF 2)

Polarimetric observations with GPI will reveal details of circumstellar disks and their interaction with planets. The data will yield quantitative assessments of the timescales for planet formation and disk clearing. Competing models of planet formation versus photoevaporation to account for the rapid clearing of disks observed in some cases will be tested. With sensitive observations of substantial samples, differences within the same cluster can be measured and explained. The sensitivity and spatial resolution will also enable further direct observations of apparent gaps and holes in some disks.

How diverse are planetary systems? (PSF 3)

The planned GPI science campaign, which will survey 600 nearby, young stars will move beyond mere exoplanet census to measure the demographics of the population. It will yield a comprehensive and statistically robust study of exoplanet occurrence from 5 to 200 AU separation from the parent star. For each discovered planet (estimated to be around 50), GPI spectrophotometry will give effective temperature and luminosity. Careful astrometric measurements will also determine orbital motion and therefore semimajor axis, a key parameter of interest. Measurements of the eccentricity distribution of some of the population will also be possible, which will distinguish among various evolutionary states with high confidence, further testing models of formation and migration.

Do habitable worlds exist around other stars, and can we identify the telltale signs of life on an exoplanet? (PSF 4)

Exoplanet spectroscopy with GPI will reveal atmospheric conditions and thermal history of large Jovian planets, thereby calibrating atmosphere and accretion models. In particular, multi-band and multi-epoch observations will test planet rotation timescales and rotational symmetry of planet atmospheres. The physical scale of the systems probed will be comparable to our own Solar System, providing effective comparisons with our local habitable zone.

How do stars form? (PSF 1)

In addition to the upcoming GPI, Gemini enables key observations in the study of star formation, with detailed studies of star formation regions combining AO with ALTAIR and NIFS. ALTAIR can provide up to 65 milliarcsecond resolution in the NIR, where visibility is optimal for these dusty regions. This resolution is finer than that of HST at the same wavelength. In addition, NIFS provides over 2000 simultaneous spectra over the 3 arcsecond x 3 arcsecond field of view, which is compatible for observing these Galactic regions.

The window that GeMS with GSAOI (or FLAMINGOS-2) opens is the ability to observe simultaneously multiple examples of stars in formation across an entire field. Crowding comparable to the Orion Nebular Cluster becomes resolvable to distances of 15 kpc, and direct measurement there of the initial mass function to substellar masses becomes possible.

3.3 Galactic Neighborhood

Studies in the Galactic neighborhood take advantage of the high spatial resolution and high signal-to-noise that observations of local objects offer, leveraging them as a laboratory of fundamental astrophysics applicable broadly across the history and scope of the Universe as a whole. The particular contributions Gemini stands to make in this area stem from its high angular resolution performance and availability of a range of optical and infrared instruments.

What is the fossil record of galaxy assembly from the first stars to the present? (GAN 3)

Observations in the infrared will probe deeply into dusty regions, with resolution to identify individual stars. The star formation histories of nearby galaxies can be gleaned from color-magnitude diagrams, with the NIR probing the cool stars of the red giant branch and asymptotic giant branch. Using adaptive optics, observations go beyond the Magellanic Clouds to other members of the Local Group (e.g., Davidge 2010 ApJ 718 1428). GeMS and GSAOI literally expand the field of view for the required imaging.

Galactic archaeology will proceed with abundance studies of individual stars, which GHOS and GRACES will enable. The metal-poor candidates are the most relevant, revealing the formation history of the first generations of stars and the initial mass function.

What are the connections between dark and luminous matter? (GAN 4)

The fossil record of formation of the halos of the massive members of the Local Group appears in the discovery of their dwarf satellite galaxies. The number and distribution of these depends sensitively on the nature of dark matter and its distribution. Deep optical observations from large telescopes such as Gemini extend the depth of these discoveries, eventually making possible the completion of samples to distances of 1 Mpc (e.g., Bell et al. 2011 ApJL 742 L15).

3.4 Stars and Stellar Evolution

High resolution optical spectroscopy offers a critical probe of the lifecycles of stars. The new Gemini instruments to be offered in the near term, GHOS and GRACES, will be used extensively in this area. Some specific properties that must be determined are mass loss, rotation, and magnetic field. These measurements will answer fundamental questions about stellar evolution—**How do rotation and magnetic fields affect stars? (SSE 1); How do the lives of massive stars end? (SSE 3)**—which are ultimately connected to the lifecycles of galaxies, including the interplay of gas, metals, and energy they contain.

Gemini will continue to observe the explosive end states of stars as supernovae. **Understanding progenitors and trigger mechanism of the Type Ia supernovae (SSE 2)** is important both for the sake of stellar evolution and to better calibrate these sources that serve as crucial cosmological probes. The Type Ia supernovae appear to be "more standard" candles in the NIR, and extinction corrections are smaller, so Gemini's complete NIR capabilities will continue to play an increasingly important role as these characteristics are better understood and exploited. **The end states of massive stars (SSE 3)** will be observed as Type II supernovae and gamma-ray bursts. The crucial role for Gemini in all these studies of stellar death will continue to be follow up observations, especially spectroscopy, after discovery elsewhere. The existing capabilities—optical and infrared spectroscopy from both hemispheres—and observing mode—dominantly in queue, with rapid interruption possible—will be vital, and new capabilities, such as GIROS, will open new possibilities for rapid characterization of fading sources using broad wavelength coverage.

3.5 Cosmology and Fundamental Physics

As a general-purpose facility executing individual investigator-led programs, Gemini will not perform the large-scale experiments that will provide the high-precision measurements required to answer the key questions in fundamental physics. The contribution in this area will be indirect, though still relevant. For example, progress in the near-term to answer **Why is the Universe accelerating? (CFP 2)** must come from existing facilities, so Gemini observations of distant supernovae to trace cosmological evolution have been and will continue to be vital. Programs over the next five years will not provide a definitive answer to the question **What is dark matter (CFP 3)**, but other work described above, including studies of the Galactic neighborhood and its population of dwarf galaxies and observations of individual galaxies that yield quantitative measurements of their central black holes and dark matter halos, will continue to be critical evidence for testing models of dark matter. The **properties of neutrinos (CFP 4)** are tied to nucleosynthesis in the big bang, which emerges in sensitive abundance measurements of light elements in stars that will be possible with GHOS and GRACES.

. . .

Gemini has been and will continue to be utilized to pursue fundamental questions in planetary science; some of those from *VV* are described here. The core strengths of Gemini, including sensitivity, IR capability, and the temporal flexibility of queue scheduling, are particularly valuable. Roughly 10% of time on Gemini North and about half that at Gemini South have been dedicated to non-sidereal observations. Coordination between space missions and ground-based facilities like Gemini has enhanced the scientific results, as examples from Deep Impact (Harker et al. 2005 Science 310 278) and EPOXI (Meech et al. 2011 ApJL 734 L1) among others show, and such collaborative efforts will continue to be useful.

3.6 Building New Worlds

What were the initial stages, conditions, and processes of solar system formation and the nature of the interstellar matter that was incorporated? (Q1)

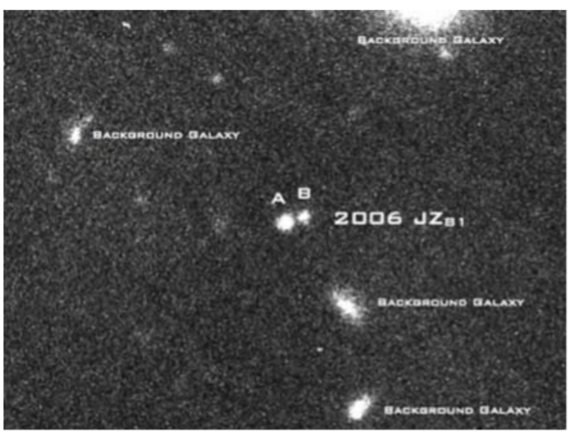


Figure 3-3: Original GMOS-N observation shows both members of the Kuiper belt binary system 2006 JZ_{81}, separated by about 1.3 arcseconds. (Credit: Parker et al. 2011 ApJ 743 1.)

Various classes of small, primitive bodies contain the answer to this question. They are relatively faint, so require large ground-based telescopes for observations. Comets still harbor water ice and other volatiles that are remnants of the solar system formation. Diagnostic emission frequently arises at long wavelengths, from the near- to mid-IR. Gemini observations have been used to determine mineralogy and grain size distribution, for example, which can be related to the formation sites of comets (Harker et al. 2011 AJ 141 26).

What governed the accretion, supply of water, chemistry, and internal differentiation of the inner planets and the evolution of their atmospheres, and what roles did bombardment by large projectiles play? (Q3)

Kuiper belt objects (KBOs) are the most primitive bodies in the solar system, located far from the Sun. Their ices are best observed in the NIR, and may reveal the conditions that account for the early evolution of inner planets. A fundamental dynamical quantity of the KBOs is the fraction of binaries. The surprisingly large fraction of binaries (10 to 25%) is likely a consequence of events during the planet-forming era. Gemini observations have been valuable in the characterization of these orbits, taking advantage of optimal seeing in the queue to obtain relative astrometry on scales of 0.02 arcseconds (Figure 3-3). These orbits ultimately constrain formation scenarios, while also giving system mass. More KBO systems will be observed in the future, with their properties and distribution also giving evidence about the migration of giant planets.

3.7 Planetary Habitats

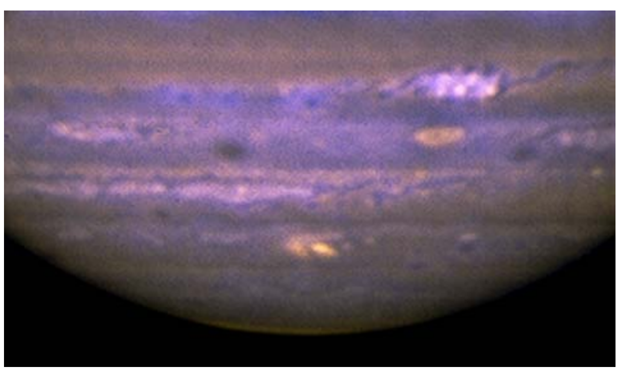
What were the primordial sources of organic matter, and where does organic synthesis continue today? (Q4)

Main belt comets offer a new class for study, being located within the asteroid belt yet exhibiting the cometary emission. These bodies could be responsible for the delivery of water to the early Earth. Their emission is typically fainter than 25 magnitudes per square arecsecond, demanding large aperture for ground-based observations. Still only a handful of these objects have been identified, with several discoveries and confirmed identifications relying on observations with Gemini (e.g., Hsieh and Jewitt 2006 Science 312 561; Hsieh et al. 2012 AJ, submitted).

3.8 Workings of Solar Systems

What solar system bodies endanger and what mechanisms shield Earth's biosphere? (Q8)

Observations of the orbits and rates of Jupiter impactors are relevant to understanding similar effects on Earth. They are probes of the populations of potential impactors, and studies of their orbits can show whether Jupiter protectively deflects them away from Earth or harmfully sends them toward us. Important studies of the 2009 and multiple 2010 Jupiter impacts using Gemini further illustrate their utility in probing the giant planet's atmosphere (Figure 3-4).



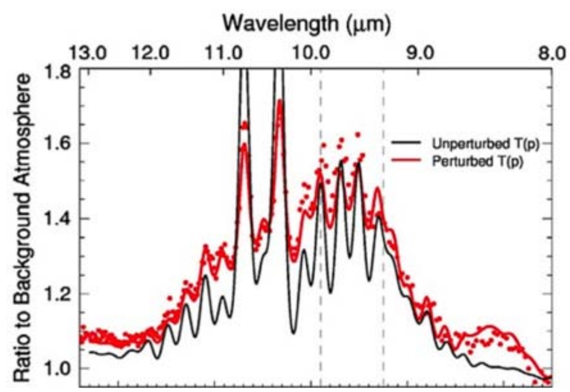


Figure 3-4: (left) Gemini/Michelle MIR image shows the 2009 impact as thermal emission (yellow region at the lower center of Jupiter's disk). Credit: I. de Pater/H. Hammel/T. Rector/Gemini/AURA. (right) The Gemini/T-ReCS spectrum of the impact site (red points) shows evidence for silicates, indicating a rocky body impact (Credit: Orton et al. 2011 Icarus 221 587.)

Can understanding the roles of physics, chemistry, geology, and dynamics in driving planetary atmospheres lead to a better understanding of climate change on Earth? (Q9)

Titan is an excellent analogue for understanding Earth's weather cycles. Titan has roughly one atmosphere of pressure, with methane rather than water the molecule of action. The satellite's 0.8 arcsecond diameter disk as seen from Earth is well resolved using AO on Gemini (Figure 3-2), and the NIR observations are preferable to optical for transparent views of the atmosphere. Long-term monitoring of these storms is key to climate studies, and possible with Gemini's flexible scheduling. Dynamic cloud features on the gas giant planets also appear in long-term investigations, revealing seasonal variations.

3.9 Discovery Potential: Time-Domain Astronomy

A strong thread through many of the scientific questions that *NWNH* and *VV* pose is the discovery potential of time-domain astronomy. Gemini's operational flexibility, including the queue and response to ToOs, will be powerful tools to develop answers in response.

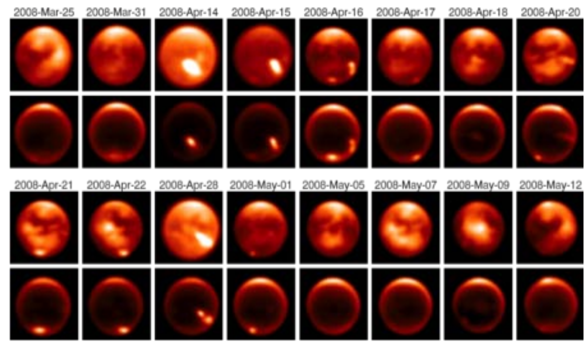


Figure 3-3: Gemini NIRI/ALTAIR adaptive-optics image sequences of Titan in several bands show the obvious tropical storm on 2008 April 14 rotated back to observable limb on April 28. (Credit: Schaller et al. 2009 Nature 460 873.)

Because full or adjacent nights need not be allocated to programs, the queue enables punctuated observations, which is useful in the study of variable sources. This approach has already been employed with the systematic monitoring of Titan, Saturn's largest moon, using NIRI and ALTAIR AO at Gemini North, to give a full picture of the satellite's weather. A key result has been the first detection of bright, transient clouds in the tropical latitudes of Titan (Figure 3-3). The initial pulse of tropospheric cloud activity generated planetary waves that instigated more cloud activity at other latitudes across a moon that had been cloud-free for at least several years. These new findings may explain the presence of dunes and methane-carved rivers and channels without the need to invoke once-per-century storms.

Gemini will continue to observe transient sources as targets of opportunity over the next five years. Running a multi-instrument queue means that the full range of observations with all mounted instruments is possible when required, to follow newly-identified targets rapidly. Current and upcoming surveys, including Pan-STARRS, the Palomar Transient Factory, and LSST will provide many candidates of interest to a range of subjects, especially relevant to questions of the Galactic Neighborhood, Stars and Stellar Evolution, and Galaxies Across Cosmic Time. New Gemini instruments, including the proposed Gemini Infrared-Optical Spectrograph (GIROS; see Section 5.1.3.1), which will provide simultaneous spectroscopy over a broad wavelength range, will be particularly effective to discover the nature of truly unknown sources.

4. Past Work: Science, Operations, and Facilities

4.1 Science Operations

4.1.1 Publications

More than 1000 papers based all or in part on Gemini observations have been published in principal refereed journals, and more than an additional 100 papers at SPIE conferences have been presented. The scientific work shows the typical gradual development of a new facility after it first becomes available for research use (Figure 4-1), with 182 publications in 2011. Gemini North, with a full complement of instruments, is now mature, responsible for the majority (106) of the latest annual results.

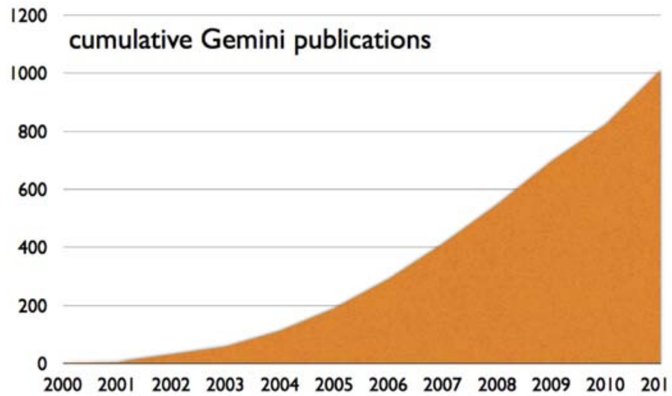


Figure 4-1: Refereed publications based all or in part on observations with Gemini, by year.

4.1.2 Observing Modes

Gemini's observing model includes a multi-instrument queue-observing system that efficiently fulfills users' observing requests. In this *queue mode*, on a given night staff observers execute a mixture of observations from different science programs, chosen as the best matches to the observing conditions (clouds, image quality, moon, water vapor, etc.), available instruments, and the scientific priorities established by the telescope time allocation process. This queue system has made Gemini one of the most effective target of opportunity (ToO) observing systems available, both for fast-response targets (e.g., transients like GRBs) and slow-response follow-up targets (e.g., distant supernovae or newly discovered asteroids). Our ToO capability is further enabled by the average 15-minute data-delivery time from the Gemini Science Archive (GSA) to the Principal Investigators (PIs).

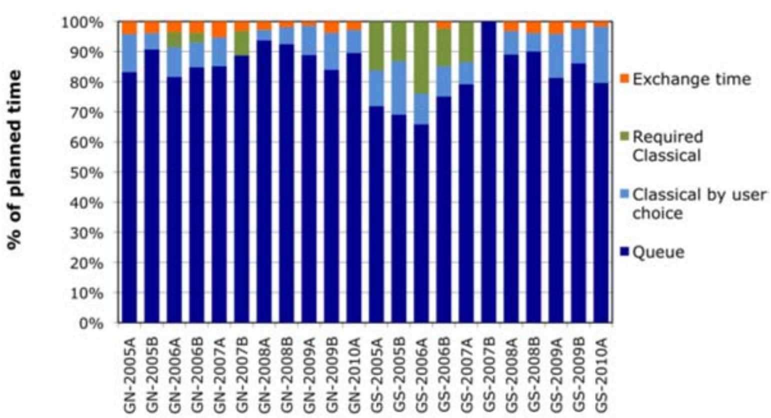


Figure 4-2: Distribution of planned science time is shown. The increase in the user-choice classical time in 2009 is primarily due to the US Time Allocation Committee choosing to schedule more US programs in classical mode. The visitor instrument TEXES, a high-resolution mid-infrared spectrometer, was only offered in classical mode ("Required Classical").

Gemini also welcomes *classical mode* observers, where the user is allocated specific night(s) and is present at the telescope collecting the data, assisted by a Gemini staff member. Classical observers ensure that programs requiring special acquisition procedures or immediate PI data assessment are executed correctly and efficiently. Classical observing also provides unique opportunities for face-to-face interaction between the users and Observatory staff.

The distribution of programs between queue and classical mode is primarily set by user demand (Figure 4-2). In the period 2005-2009, on average 8.7% of the planned time was classical by user choice.

4.1.3 Improving Software for Users

Gemini has begun an initiative to deliver major improvements in the software that users employ, namely the Phase I Tool (PIT) and the Observing Tool (OT) that they use during Phase II of observation preparation. Staff and NGOs have worked to improve the process, especially by manually providing more accurate "skeletons" of the planned program. This process will eventually become more automated. Some improvements are already available for 2012A, including "smart" calibrations, which use the science configuration information to define the calibration set-up. A second major initiative is to automate the guide star selection, to fully use the information available about various guide star catalogs and the observing requirements such as magnitude limits that depend on observing conditions.

Improvements to the PIT will be in use for 2012B. Decision trees will guide PIs through the instrument configuration, presenting only the resources that are relevant to the program. Basic guide star selection will be automated, and the meaning of conditions bins will be clearer. Finally, Word and LaTeX templates will be used for science and technical justifications, allowing formatted text and figures to be uploaded as a single PDF file. Further developments of the PIT and OT will be introduced later, including better editing capabilities in the OT and automated standard star observational sequences. The Gemini software and science teams are working closely with the NGOs and users in this project, to ensure that the delivered capabilities match their needs.

4.1.4 Performance Metrics

The operations performance is tracked through the completion rates for queue programs, open shutter efficiency, acquisition times and weather losses for both telescopes. The details of these metrics are maintained on the Gemini public web site and are accessible online[2].

4.1.4.1 Queue Completion Rates

Gemini aims to deliver complete datasets with the highest science-ranked programs having priority. We strive to complete queue programs once they have been started, to ensure that the science team can produce a refereed publication. The highest-priority Band 1 occupies 30% of science time, with 30% going to Band 2, and finally 40% of the time is for the lowest-priority Band 3.

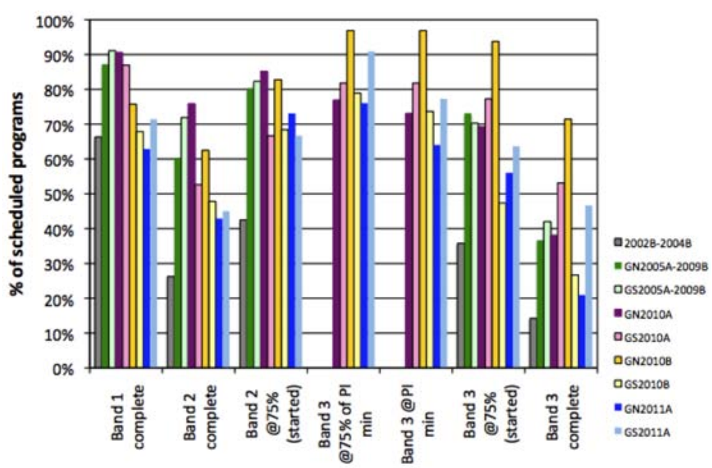


Figure 4-3: Completion rates by scientific-ranking band from 2002B through 2011A are plotted. Gemini North and South are shown together for semesters 2002B-2004B. In later semesters Gemini North and South are shown as "GN" and "GS". Time lost to poor weather or technical problems affect the completion rates**.**

Figure 4-2 shows the completion rates over time. The changes implemented in 2005 have led to a significant increase in the completion rates compared with earlier semesters. Most noticeable, the completion rate for Band 2 programs jumped from >30% to >60%. Beginning with semester 2004A, some Band 1 programs were given rollover status, allowing an incomplete program to remain active in the queue for a total of three semesters. Thus, 2010 and 2011 Band 1 completion rates are expected to increase further.

Due to time lost to poor weather,

[2] www.gemini.edu/sciops/telescope/SciOpsStats/sciopsstats.html

most Band 3 programs will not get data. Band 3 programs have historically overfilled the queue to accommodate uncertain and changing conditions, so that only ~1/3 of Band 3 programs will be executed during a nominal weather-loss semester. A recent change (since 2011A)—to deliver more complete observations to the scientists who plan them—is to underfill the Band 3 queue. Figure 4-3 shows that 70 to 80% of the Band 3 programs that are started have received at least 75% of requested data, and in the future, we expect the fraction of started Band 3 programs to increase, while maintaining similar or better completion rates.

4.1.4.2 Open Shutter Efficiency

Gemini tracks *open shutter efficiency* – the fraction of the time on the sky that a science instrument is collecting photons. The open shutter efficiencies for GMOS-North and –South (GMOS-N and GMOS-S) are now both 70.5% on average. The open shutter statistics shown in Figure 4-4 are consistent with those from other 8-10 m telescopes for comparable instruments and modes. This Figure shows the comparison for similar instruments or combinations of instruments for two periods.

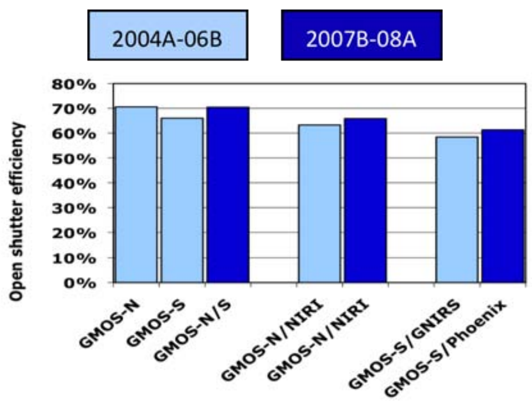


Figure 4-4: Open Shutter Efficiency: light blue: Aug 2004 - Feb 2006. Dark blue: August 2007 – July 2008. For comparable instruments or combinations, the open shutter efficiency has increased 2.5-3%.

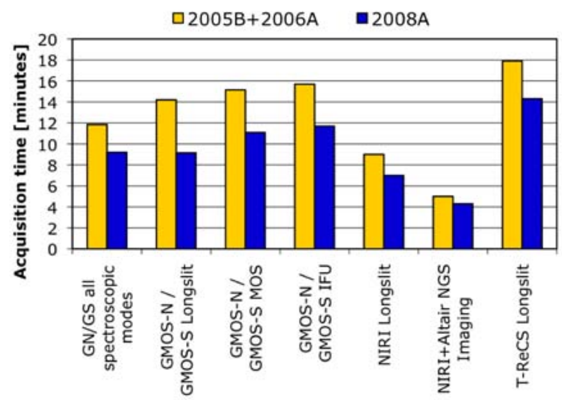


Figure 4-5: Individual instrument mode acquisition time statistics for 2005B+2006A compared to 2008A. Decreasing acquisition times show improvement.

4.1.4.3 Acquisition Times

The time required to acquire a new target with a given science instrument is also closely tracked. The median time required to slew the telescope to a new position and acquire a new-target guide star is about six minutes. There is an additional time overhead depending on the instrument mode.

Figure 4-5 shows the comparison of the average acquisition times at Gemini North and Gemini South for all spectroscopic acquisitions in selected instrument modes for two different periods. All acquisition times have improved by about three minutes per spectroscopic acquisition, which saves *three nights* of observing time at each site per semester. Gemini acquisition times are about 30% shorter than those at VLT.

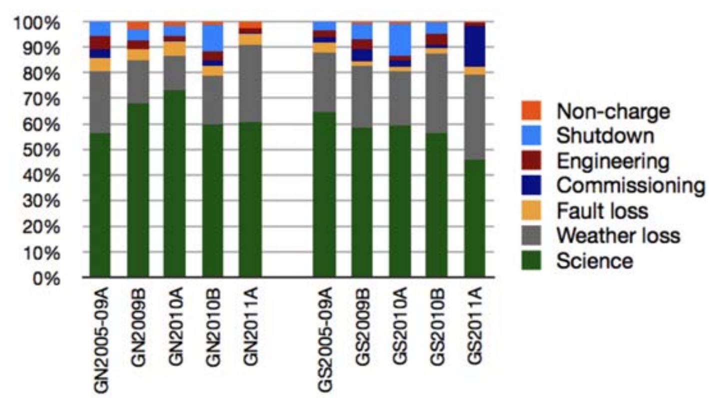


Figure 4-6: Night-time use fraction. The distribution of time between science, weather loss, technical losses, and various engineering and commissioning activities is plotted, for Gemini North and South separately.

4.1.4.4 Delivered Science Time

The Gemini Director recommends to the Gemini Board the number of science nights to be offered each semester. Weather loss will affect the amount of science time on the sky. Figure 4-6 shows the actual distribution between science time, weather loss, technical losses, commissioning, engineering, and telescope shutdowns.

4.1.5 Opportunities for Visiting Observers

Gemini welcomes users to visit the Observatory and participate in the observing process. The Gemini operations model affords this possibility in two main ways: through the traditional "classical" observing mode and by encouraging queue PIs to visit while their programs are in the queue. Exchanging information between scientific staff and the user community, both of these modes improve operations and effective use of the Observatory's capabilities.

4.1.5.1 Classical Observers

Some observations can best be done (and in some cases *only* done accurately) with a member of the project team at the telescope. Time-critical observations with a high data-acquisition uncertainty, which may require real-time strategy changes, benefit the most from the classical mode. A Gemini astronomer assists all classical observers throughout their runs.

4.1.5.2 Visiting Queue Observers

A new way for Gemini users to participate in data collection is as *visiting queue observers*. Gemini makes every effort, within the constraints of priority and weather conditions, to schedule the visitor's approved queue program while the PI is at the telescope. While there is no guarantee that the PI will see the program executed, this system has been both popular and successful. This approach is particularly useful for students who come for two to three weeks, during which they have the opportunity to fully participate in observatory life.

In semester 2008B the massive star Eta Carinae erupted. This program required several epochs of observations over the semester, a program well suited to queue observations. One of the Co-Investigators visited Gemini South over a two-week period, and participated closely in several observations, both from the summit and the base facility in La Serena, describing his time as "one of the best observing experiences of my career."

4.1.5.3 Remote Data Interaction

Rapid ToO programs take advantage of the quick data access from the GSA. PIs have been known to complete preliminary data analysis of the initial data and request follow-up observations within the same night. The quality of Gemini's networking and video infrastructure, and the rapid data access through the GSA, make remote data access effective at Gemini. Currently, PIs of rapid ToO programs are most likely to take advantage of this accessibility during observations. Gemini is exploring methods for staff astronomers to interact more with PIs of regular queue programs during the night.

The NICI planet search campaign at Gemini South (PI Liu, University of Hawai'i) is being conducted in a *block-scheduling* mode within the queue, requiring clear sky and very good image quality. Campaign target selection is a complicated process that the PI team modifies in real time. Team members located at the University of Hawai'i access their data within minutes from the GSA in Victoria and then provide feedback to the observers in Chile via a live video link.

4.2 Science Data Management and Products

4.2.1 Data Management and Gemini Science Archive

Gemini generates significant amounts of data that must be managed from acquisition until delivery to the Gemini Science Archive (GSA) and ultimately the PIs and other science users. The Observatory has three main responsibilities with respect to the raw data that it generates:

1. Ensure the integrity and quality of the data acquired,
2. Distribute the data to the Principal Investigator in a timely way, and
3. Offer data via the public GSA after a suitable proprietary period.

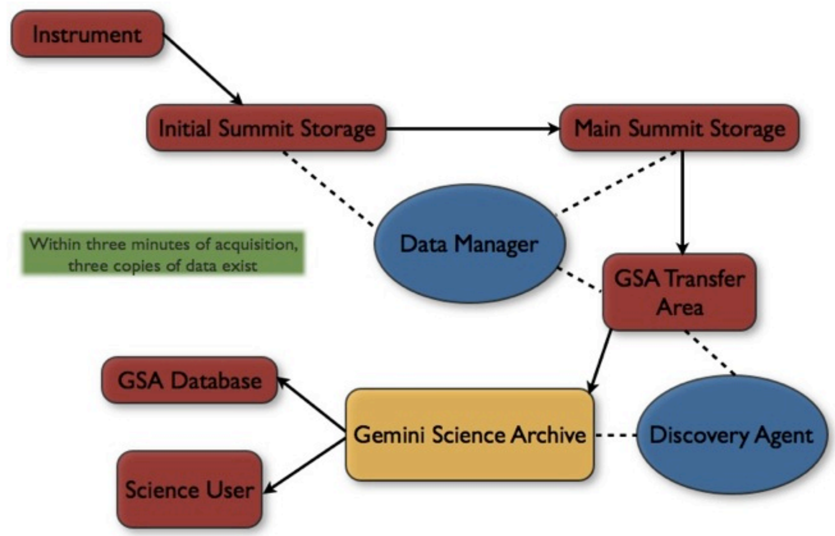


Figure 4-7: Overview of the flow of data from the instrument used to acquire data to the Gemini Science Archive.

The Gemini automatic system delivers raw data from the instrument to the GSA with an average time of 15 minutes. Once the data are in the GSA, they are available to the PI for downloading. Figure 4-7 gives a top-level view of the flow of data from the instrument to the GSA and the PI.

Gemini guarantees that the data for each science program match the requirements specified by the PI and that the instrument performs nominally during the data acquisition. Gemini Data Analysis Specialists assess the quality of each science observation. If the data set quality is found to be unacceptable by the PI, Gemini will repeat the observation.

The GSA handles data distribution to PIs and serves as the permanent repository of all Gemini science data. The GSA architecture was developed and built by the Canadian Astronomy Data Centre (CADC) at the Herzberg Institute for Astrophysics (HIA), in Victoria, BC, Canada, under the auspices of the Canadian National Research Council, and the CADC hosts the archive. The GSA is accessible worldwide. Data obtained for *all* science programs are made available to all of the international astronomical community through the GSA as a public and searchable archive.

Some usage statistics are shown in Table 4-1. The operation of the GSA is currently under a five-year (2008-2012) contract with the HIA. They maintain the archive's hardware and software infrastructure, and support the user interface. Long-term provisions in the HIA contract ensure that the Gemini data are preserved for future generations. Gemini science data have a proprietary period of 18 months and then become public.

4.2.2 Data Reduction Software

Total datasets (#, size)	2,475,150 9.41 Tbytes
Proprietary science datasets* (#)	109,459
Public science datasets* (#)	483,011
2010 annual results	
Volume transferred	5.07 Tbytes
Volume retrieved	1.55 Tbytes
Proprietary data users (#)	427
Countries represented (#)	20

Table 4-1: GSA snapshot as of December 2010.
*Note that science datasets do not include calibrations, logs, or weather data.

Gemini is committed to providing data reduction tools that run on an open (non-proprietary) platform. The original system was developed for Image Reduction and Analysis Facility (IRAF), originated by the National Optical Astronomy Observatory (NOAO). Gemini data reduction packages are used by more than 75% of its users[3]. The Observatory is working with the Space Telescope Science Institute (STScI) to modify the Gemini data reduction software to run under Python scripting-language version of IRAF called PyRAF. The Observatory will continue to develop advanced reduction software and recipes, emphasizing interactive user tools.

A separate work of the data processing team is to develop quality assessment tools for nighttime use at the telescopes. The first tools, which provide automatic reduction and data assessment of GMOS imaging (with quantitative measurements of image quality, for example) are now running at both sites. Perhaps more important is the complete infrastructure behind these tools, which will facilitate future development. As a result, extending the system to additional instruments and modes is straightforward. Moreover, some of the underlying processes that these tools require, such as a calibration database manager, may be extended for scientific use for PI and public data in the GSA**.**

4.3 Telescopes and Systems

4.3.1 Primary Mirrors

The two Gemini telescopes now achieve outstanding performance in the thermal infrared regime with an emissivity of less than ~3% – the best of any ground-based facility. This is achievable because both telescope primary mirrors have protected silver coatings, based on a formulation developed at Gemini. The durability and quality of those coatings, coupled with preventive maintenance techniques, have increased the interval of time between re-coatings to a nominal five years (two to three times longer than the conventional coatings used at other facilities).

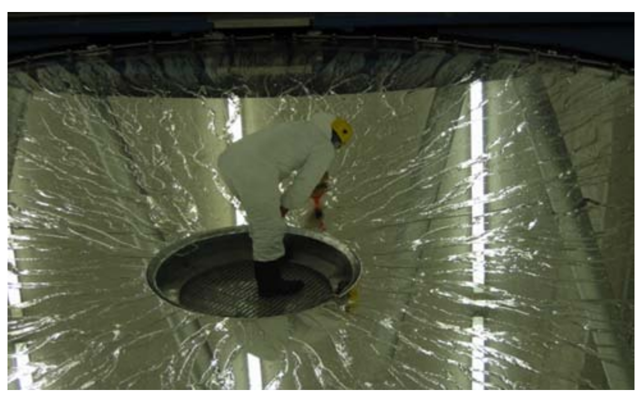


Figure 4-8: Primary mirror *in situ* wash process. Water is being flowed over the mirror.

One of the techniques contributing to this extended coating lifetime is a procedure that permits the primary mirror to be literally washed in place in the telescope. Semiannual *in situ* washing (Figure 4-8), combined with weekly CO_2 cleaning, significantly lengthens the coating lifetime over CO_2 cleaning alone, and maintains the quality of the mirrors' protected silver coating. In fact, the reflectivity of the mirror coating can be restored to nearly its original new-coating level through *in situ* washing. The limiting

[3] 2008 Gemini Users' Survey

factor of this process is that each wash tends to weaken the bond between the coating and substrate, so only a finite number of washings are feasible.

In addition to superb reflectivity, the image quality delivered to the detectors has been excellent at both sites (median FWHM R-band ~0.6 arcsec and K-band ~0.4 arcsec).

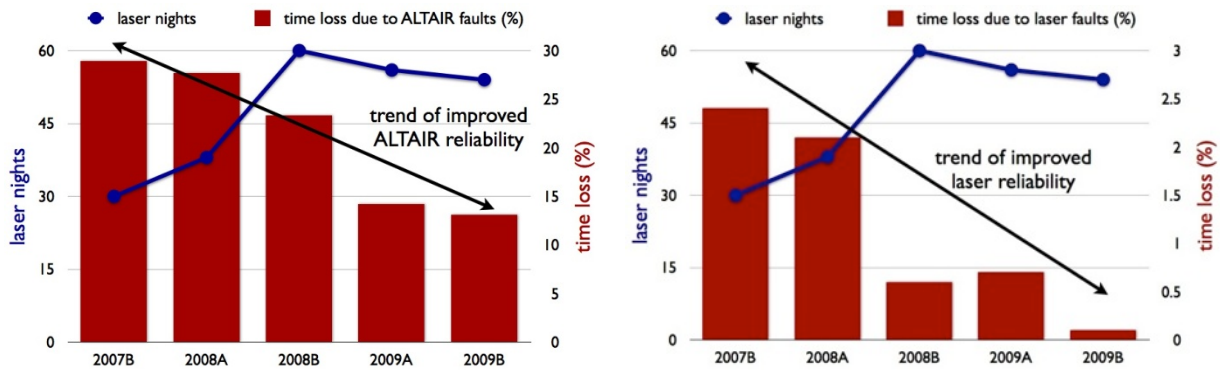


Figure 4-9: Technical and operational refinements have led to significant reductions in the amount of time lost to AO (left) and LGS (right) system faults at Gemini North.

4.3.2 Laser Guide Star Adaptive Optics – North

The Gemini-North Laser Guide Star (LGS) Adaptive Optics (AO) system saw first light in May 2005, which was followed by 20 months of commissioning to integrate the LGS facility with the AO bench (ALTAIR) and the science instruments. As a workhorse facility supporting many instruments, the system provides robust point-and-click operations. When LGS AO science operations began in February 2007, the engineering environment was complex. The engineering staff addressed laser system faults, automated various subsystems, refined the overall support model, and broadly cross-trained the support staff.

In September 2008, the laser support team initiated a new era in laser operation support with demonstrably better system performance and reliability (Figure 4-9). The Gemini North LGS AO system now routinely meets current science demand, providing 110 nights per year. These developments not only benefit Gemini North, but will also be invaluable for the operational support of next-generation AO systems across all of Gemini.

4.3.3 Laser Guide Star Adaptive Optics – South

The latest progress on GeMS is described above (Section 2). The key GeMS subsystems behind those developments include:

- A 50-W solid-state laser projecting a constellation of five artificial guide stars on the 90km high sodium layer, allowing full tomography of the atmosphere in the telescope's line-of-sight;
- Canopus, the advanced adaptive optics bench with three deformable mirrors and multiple wavefront sensors;
- A system of beam transfer optics used to relay the laser beam from the Nasmyth service platform laser to the laser launch telescope at the back of the secondary-mirror tip-tilt system;
- Infrastructure accommodating new equipment, including a seven-ton structure erected on the telescope to support the laser service enclosure and the laser itself; and

- The Gemini South Adaptive Optics Imager (GSAOI), a 4Kx4K near-infrared camera that will serve as the main imager for GeMS.

Monitoring aircraft in the vicinity of the Observatory is a basic requirement for projecting a powerful laser beam into the sky. Gemini entered into a partnership with VIA56 S.A., a Chilean company that has designed and deployed a real-time aircraft detection and monitoring system, VIsualizador de TRansito Oceanico (VITRO), to follow Chilean continental and oceanic flights. A modified version of VITRO was tested at Gemini South on Cerro Pachón in August 2010. Laser spotters are now using the system monthly to derive its dependability statistics. VITRO will be integrated with the laser traffic control system that prevents contaminating neighboring telescope facilities' observations with laser light.

4.4 Instruments

The two Gemini telescopes are instrumented with a broad range of optical and infrared cameras and spectrographs. See Table 2-2 and the Gemini website[4] for more information. All mounted instruments are available during the night for execution of queue observations, allowing flexibility and agility to complete users' programs. All current and planned NIR instruments can receive an adaptive optics feed, while MIR instruments are inherently diffraction-limited.

[4] www.gemini.edu/sciops/instruments

5. Future Plans

The Gemini Observatory is an essential part of the international astronomical infrastructure and a major component of the US and other Gemini partners' programs. The work planned for 2012–2015 aims to advance knowledge and understanding of the Universe and our origins. The research frontiers are discussed elsewhere (Section 3); here we concentrate on plans for the facility to enable those scientific advancements.

5.1 Instrument Initiatives

Advancement in astronomy depends vitally on new technologies in instrumentation because these developments are essential to asking—and answering—new and more demanding questions about the nature of the Universe. During the 2012-2015 period, we plan to enhance Gemini's instrument suite by upgrading current instruments and adding new capabilities.

5.1.1 Improvements to Current Instruments

Several existing instruments will be modified for greater scientific performance. Upgrade efforts are in progress now, such as replacing the GMOS-N CCDs with much more red-sensitive detectors, replacing aging detector controllers and consolidating to fewer types, and purchasing new narrow-band filters for FLAMINGOS-2. Further upgrades we propose to complete over the new proposal period, largely using contracted effort, are listed below.

5.1.1.1 GMOS-S Upgrade

The CCD detectors and control electronics used in GMOS-S are obsolete. We propose replacing them with new, more sensitive CCDs and faster electronics. The new CCDs will have higher quantum efficiency and dramatically wider spectral coverage maintaining the existing blue sensitivity while enhancing the red sensitivity. The ongoing GMOS-N effort will inform this project, resulting in state-of-the-art cameras that enable optical spectroscopy to wavelengths as long as 1 μm on both Gemini telescopes.

5.1.1.2 ALTAIR Upgrades

The Gemini North ALTAIR AO system now routinely produces near-diffraction-limited images with a point-spread function that is stable for weeks or more. In the five-year timeframe, we intend to introduce several improvements that will make ALTAIR even more productive. Upgrades to the opto-mechanical components and the laser system will improve reliability and greatly enhance operational efficiency. Improvements to ALTAIR optics and tip/tilt wavefront sensors will increase the current sky coverage area accessible by more than a factor of two and bring the system close to its highest possible performance level.

5.1.1.3 GNIRS OH Suppression

OH airglow is the dominant source of background in the near infrared. Removing it would make GNIRS much more sensitive, reducing the background by a factor of ten or more through the installation of specialized fiber optics tuned to suppress the wavelengths associated with atmospheric OH emission. Reducing errors in sky subtraction would increase the sensitivity and efficiency of the science programs that require faint-object NIR spectroscopy. These include studies of the atmospheres of faint brown dwarfs and extrasolar planets, measuring stellar properties and black-hole formation in very young galaxies at various redshifts, and probing the properties of very high-redshift gamma-ray bursts and the galaxies that host them.

5.1.2 New Instrument Plans in Progress

The user community, especially in the US, desires high-resolution optical spectroscopy capacity. We are currently moving ahead with two instrument initiatives—GHOS and GRACES—to offer this at Gemini; these can be implemented in a relatively short timeframe. Providing these instruments would address some of the high-priority concerns identified in both *NWNH* and the NOAO ALTAIR[5] report. With the participation of the Observatory, the STAC, and the Gemini user community, the science case to support this capability has been completed, work on two different approaches is in progress.

5.1.2.1 Gemini High-Resolution Optical Spectrometer (GHOS)

GHOS will provide high-resolution (R~40,000) spectra over the optical band. It does not require any new technology development, which minimizes risk. As an optical instrument, its optics are not cryogenic, which reduces expense.

GHOS will be a workhorse instrument for studies of the origins of the elements through stellar observations. Broad wavelength coverage would allow simultaneous sampling of multiple chemical elements and ionization states. The distant halo stars provide a good population in which to measure extremes of metallicity and age, and because their space density is low, a single-object spectrograph is suitable. This instrument will investigate the properties of planet-harboring stars, identifying the variables that influence the structure and formation of different planetary systems. The physical properties of the host stars, including metallicity, are key measurements, and high-resolution spectroscopy may also reveal the planetary atmospheres. In addition, GHOS will measure the chemical signatures in various stellar populations within the Galaxy to discern the history of the Milky Way's assembly. The relevant target densities are low, with disrupted satellite galaxies possibly responsible for substructure in the Galactic halo.

Three competing teams are currently at work on conceptual design studies for GHOS. These six-month studies will result in plans for continuing the design and building of the instrument, including resolution of the key technical risks while meeting cost and schedule constraints. The plans that result from these studies will provide the feasible schedules, with a goal of delivering GHOS in 2015.

5.1.2.2 Gemini Remote Access to CFHT ESPaDOnS Spectrograph (GRACES)

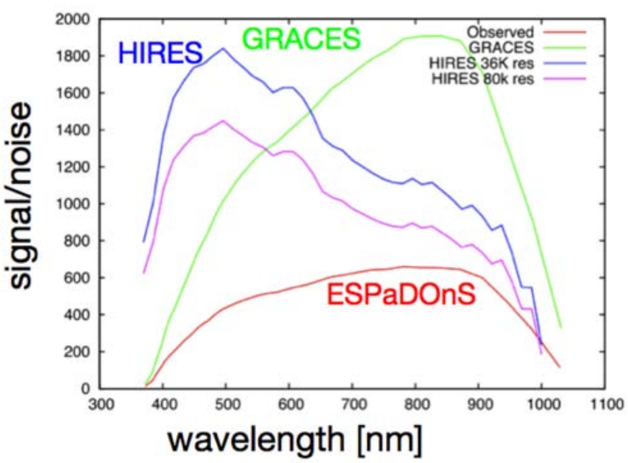


Figure 5-1: Signal/noise as a function of wavelength, for the existing instruments HIRES (at the Keck Observatory) and ESPaDOnS (at CFHT), compared with the proposed GRACES.

GRACES is an initiative to link ESPaDOnS—CFHT's visible-wavelength high-resolution (R~65,000 for "object+sky" or ~80,000 for "object only") cross-dispersed echelle spectrograph with polarimetric capability—to Gemini North via a fiber feed (Figure 5-1). ESPaDOnS has been used for the past five years, addressing a blend of programs using its polarimetric capabilities for stellar magnetic field studies, as well as purely spectroscopic observations. GRACES offers a low-cost and relatively fast option to add high-resolution spectroscopic capabilities to Gemini North. The advantages are: (1) the close proximity of the two facilities on the summit ridge of Mauna Kea, with a conduit between them; (2) ESPaDOnS is already in operation at CFHT; and (3) the instrument is available for at least 250 nights per year. The instrument is stable and well-characterized, and it comes with an efficient reduction pipeline. The cost to implement GRACES is mostly in providing the appropriate high efficiency optical fiber feed system from the CFHT to Gemini North; implementation is expected to be relatively

[5] www.noao.edu/system/altair/files/ALTAIR_Report_Final.pdf

low cost and low risk. The polarimetric capabilities of ESPaDOnS come from a module installed at the CFHT Cassegrain focus; such a module would have to be developed at Gemini if spectropolarimetry were to be of interest to the Gemini community. Design work is currently in progress, and the first phase of this work would offer GRACES for users in "visiting instrument mode" at the end of 2012.

5.1.3 Future Instrument Candidates

With the support of the Gemini Board, we are significantly changing the *approach* to instrument development funding by defining, in advance, a long-term steady instrumentation budget. We can plan within this envelope to maintain a balanced suite of instruments that the partner astronomers desire, while over time improving the total capabilities we deliver. This approach is in marked contrast to the past, whereby individual projects were funded on a "pay as you go" basis, subject to cancellation mid-stream. A further advantage of this funding system is that it allows for more frequent instrument starts. Thus, projects can be initiated within the most current context of scientific interests and technical capabilities.

With the nominal planning budget of ~$25M through 2015, we anticipate completion of the instrument upgrades and high resolution optical spectroscopic capabilities described above, and also the start of two additional instruments (to be completed in the following 5-year period). Given Gemini's strengths, strategic plans, and scientific interests, and taking into consideration technological feasibility, we list here a *representative* set of instruments and upgrades for the Gemini community to consider for this time period and beyond.

5.1.3.1 Gemini IR-Optical Spectrograph (GIROS)

GIROS would provide simultaneous wavelength coverage from 0.4-2.5 μm using multiple arms, each with its own detector. With high efficiency, this single object, cross-dispersed instrument would be ideal to identify unknown objects, such as ToOs that time-domain surveys find. It could easily measure the redshifts of gamma-ray-burst afterglows and emission-line galaxies and quasars. Observations with GIROS could also efficiently probe the formation mechanism of brown dwarfs and elemental abundances of low-metallicity stars. The abundance measurements will help to discern the structure of the Milky Way halo, thereby revealing the Galaxy's formation history. Broad-coverage spectroscopy of stellar remnants in compact binaries will also contribute to understanding the physics of accretion. Measurements of abundances and changes in emission lines of the mass-transferring stars will help in accounting for the evolution of these systems.

The STAC has recently identified GIROS as the top priority for the next new instrument capability on Gemini. They will call for and evaluate scientific white papers to refine the specific requirements during the first half of 2012. If GIROS is approved for further development, one more of the following concepts would likely be initiated during this current five-year period.

5.1.3.2 Gemini North Adaptive Optics Imager (GNAOI)

GNAOI would replace the decade-old NIRI for NIR imaging at Gemini North. GNAOI would feature a near-infrared focal plane sixteen times larger than that of NIRI with two plates scales, capable of sampling either a natural-seeing/GLAO fed beam or an ALTAIR/LGS beam. A plate scale of ~0.1 arcsec/pixel, appropriate for seeing-limited and GLAO observing, would provide a field of view of 8 arcmin across, yielding an order of magnitude increase in areal coverage per integration compared to NIRI. This enormous performance improvement would especially benefit deep surveys, such as those probing for the earliest galaxies and distant quasars. A plate scale of ~0.02 arcsec/pixel, the same used in ALTAIR/NIRI, would provide sixteen times the detector area. ALTAIR/GNAOI would provide an ~80 arcsec diameter AO-corrected field of view, ideal for sampling the full AO-corrected NIR field at Gemini North under ground turbulence dominated conditions.

The baseline design would support 1-5 micron imaging, taking advantage of the low telescope emissivity and dry conditions on Mauna Kea. The detector technology adopted would either be a 2x2 mosaic of 2048^2 detectors (like GSAOI) or a single 4096^2 detector (currently in development). A decision would be made based upon price, performance, and risk to the project at the appropriate point in the plan's execution. To simplify the instrument and minimize costs, GNAOI would not duplicate the spectroscopic capability of GNIRS. Importantly, GNAOI could serve as both the commissioning and science camera for a future GLAO system, a critical development for the AO systems at Gemini North.

5.1.3.3 Gemini High-Dispersion IR Spectrograph (GHDI)

A new high-resolution NIR spectrograph would exploit Gemini's exquisite telescope performance at NIR wavelengths and tap into a wide range of science opportunities. GHDIS would be a single-object spectrograph with a spectral resolution of R~50,000 to 70,000—well beyond that possible with any of the other available or planned Gemini spectrographs. It would represent an extension of the popular GNIRS cross-dispersed mode, by offering complete coverage over 1–2.5 or 3–5 microns in a single exposure. In addition, GHDIS would provide this coverage with ~40 times the spectral resolution, exploring entirely new research frontiers. (While the Phoenix echelle spectrograph had offered high resolution in the NIR, it provided spectral coverage of only ~1500 km/s, about 0.5% of the bandpass. The GHDIS would vastly improve coverage, to nearly 100% of the bandpass.) The key technologies required for GHDIS are a large format NIR focal plane with a mosaic of 2048^2 detectors (currently available), and a high-dispersion optical element (e.g., an immersed silicon grating). The use of silicon gratings would significantly reduce the overall instrument size (and cost) by keeping the beam size through the disperser to a minimum.

GHDIS would be a powerful workhorse instrument for the Gemini community, especially in the era of JWST. High-resolution NIR spectroscopy with large-wavelength coverage is vital to understanding the atmospheric chemistry of Solar System objects, like Mars, the Jovian planets, and KBOs. It is also needed to probe the motions and properties of gases (e.g., H_2 and CO) in disks around young stars, where planets form. GHDIS would also be used to revolutionize our understanding of star formation, as well as mass loss and accretion around protostars. High-resolution NIR spectra will be used to help understand how the building blocks of life form in the Universe, and how stars and planets form across a wide range of environments. It will also probe, at high resolution, the composition and dynamics of bright supernovae, gamma-ray bursts, and bright active galactic nuclei for the first time.

5.1.3.4 Ground Layer Adaptive Optics (GLAO)

GLAO would significantly enhance the performance of *all* the instruments at Gemini North by correcting for turbulence near the ground across a very wide field of view (~10 arcmin), at both optical and NIR wavelengths. A GLAO system would not attempt to provide high-order correction, but rather provide significant improvement in image quality for a very broad wavelength range and wide field of view. Improvements of 0.2 arcsec full-width half-maximum would directly translate into a 50% increase in flux through a GMOS slit, and a factor of two improvement in NIR slit coupling for GNIRS for point sources. In contrast to traditional AO systems, GLAO will produce good results at optical wavelengths and even when the seeing is quite poor. GLAO makes the best image quality a common occurrence: 20-%tile image quality will be achieved 80% of the time, with the direct result of completing many more observing programs.

The heart of GLAO is an adaptive secondary mirror (ASM), the deformable mirror of the system. The required laser guide stars would be measured in wavefront sensors located in a new acquisition and guiding unit (currently funded). GLAO could feed NIR instruments on the side ports, or the MIR and optical instruments on the up-looking port. The ASM also provides a major MIR AO capability. While MIR imaging and spectroscopy is diffraction limited without AO, GLAO will consistently yield Strehls of ~90-95%, compared to ~ 60% with only tip-tilt correction. The additional information in the outer Airy rings will significantly enhance the image-reconstruction opportunities.

GLAO would enable new science that would otherwise be impossible, and would improve the efficiency of all observations. Two examples of key projects enhanced by GLAO are imaging surveys searching for the first luminous objects in the Universe and studies of dark matter in the Local Group.

5.1.3.5 Process

Many factors influence the next generation of Gemini instruments, including:

- Partner funding constraints;
- Future science opportunities as expressed by the community;
- Emerging technologies that can leverage Gemini's existing capabilities and design features;
- Synergies and competition with other observatories;
- Time-exchange opportunities with cooperating facilities;
- Optimally balancing general-purpose "workhorse" and specialized "niche" instruments; and
- Replacing an aging set of first-generation instruments.

Defining upgrades and new instruments in the context of these factors requires a consultative process that has both significant input from the user communities and the concurrence of their representatives on the STAC and Gemini Board. Considerable consultation has already occurred, but there is still a need for broader community input to ensure its success. The Observatory engagement with the partner communities through national meetings over the next year will be a critical component in the short term. While the process will move forward rapidly, the Gemini Science and User meeting planned for 2012 will provide an important opportunity for the international community to reach consensus on the program that will continue in the later years.

5.1.3.6 New Instruments as Part of a Broader Plan

It is always necessary for a healthy observatory to consider the development of newer and better instrumentation. At the same time, it must also consider how best to deal with its older instruments. Choices about the evolution of Gemini's instrumentation suite must be made in consultation with the STAC and the partner communities. In addressing these issues, we face several constraints:

- Finite number of beam feeds ports for instruments, and the need for efficient queue operations,
- Inevitable instrument obsolescence and increasing unreliability,
- New science directions demanded by Gemini's community, and
- Reduced science and engineering staff to maintain and support all of the instruments.

As examples, the following decommissioning, consolidation, and site changes are being explored by the Observatory and the STAC.

> ***Consolidate MIR Capabilities:*** Given the relatively low demand from the MIR community, the MIR imaging and spectroscopy capabilities could be consolidated on one site. This capability would be preserved at Gemini North due to the drier Mauna Kea conditions compared to Cerro Pachón. This process would preserve Gemini MIR research opportunities, while better balancing capabilities with demand across our diverse community.
>
> ***Replace NIRI:*** NIRI could be decommissioned and replaced with GNAOI.
>
> ***Replace NICI:*** NICI could be decommissioned and replaced with the Gemini Planet Imager.

With these changes, each site would have an advanced laser AO system feeding both a NIR imager and spectrograph. Both sites would also offer NIR imaging and spectroscopy under seeing-limited conditions. This would support Gemini's core strengths of image quality and IR sensitivity with workhorse instruments at each site. NIR multi-object spectroscopy could be offered at Gemini South. MIR imaging and spectroscopy could be offered at Gemini North. Gemini South would feature a high-performance coronagraphic imager/spectrograph largely dedicated to a comprehensive search for exoplanets around young stars, since most are best viewed from the Southern Hemisphere.

This plan keeps many existing instruments, completes those now under development, builds new instruments, consolidates key capabilities, moves other instruments between sites, and decommissions obsolete instruments. Again, this only represents a range of possible scenarios, as the Gemini communities are refining plans and options for the coming decade.

5.1.4 Strategic Observing-Time Exchanges

We can also engage other observatories to expand the Gemini community's scientific opportunities through innovative time exchange programs, as we have done with Keck and Subaru. By aligning long-range development plans to avoid instrument duplication and share resources, "win-win" situations can be identified. For example, we anticipate expanding the existing time exchange program between Gemini and Subaru during this period, leveraging off the successful joint Subaru/Gemini science conference in Kyoto, Japan in May 2009. The capabilities of the observatories are extremely complementary, with different strengths and capabilities. Interest in the exchange is high, with eight nights swapped for 2012A.

This program will give the Gemini community access to the upcoming HyperSuprime Camera (1.5° optical imager), in addition to current facility instruments, such as HDS (a high-resolution optical spectrograph) and MOIRCS (a NIR multi-object spectrograph) in the north. The Japanese community benefits from access to the Southern Hemisphere, including the world's only facility-class laser MCAO system. Given the Japanese investment in ALMA, gaining access to a southern infrared optimized laser AO equipped 8 m telescope for follow-up observations is attractive to their community. This access exchange highlights the types of synergies that the Gemini/Subaru/Keck time exchange program can unlock, providing the respective communities with research opportunities that simply would not be possible otherwise.

5.1.5 Instrumentation Conclusions

Given the importance to both the user community and the Observatory of maintaining a vital development program, the instrument development budget is reserved exclusively for that purpose; none of it is applied to make up for losses in the operations area. The program is implemented with a refined procurement process and guided by the needs of the partnership. Given the myriad of factors affecting Gemini's instrument program, the Observatory's approach toward, and emphasis on, near- and long-term instrument development is fully in line with our highest priority – to "*deliver and operate high-quality instruments that represent the priorities of our community*".

5.2 Future Science Operations

Gemini considered a wide range of models for science operations in response to future budget challenges. Key criteria for evaluating the different options are 1) total science productivity of the Observatory; 2) needs and desires of its international astronomical partnership; and 3) feasibility within the sustainable budget envelope. We propose to maintain significant queue observing while still offering classical observing for users who desire it, consistent with the direction of the Gemini Board. Cost savings will be realized by reducing the human effort of planning, executing, and checking the results of queue observing, reducing the total scientific research effort of the Observatory staff, and introducing non-research observers.

5.2.1 Observing Modes

User choice determines the current balance of observing modes, with 90% of time in queue and 10% classical. The operations plan can sustain this fraction. It can also accommodate a somewhat greater fraction of classical observing driven by user choice, although planning for and requiring a different ratio would not result in significant cost savings. We estimate a net cost savings of ~$200k per year in Gemini's expenses by migrating to a fully classical model, compared to the revised queue model developed here[6], although increased expenses would be shifted to PIs to conduct their observations.

Classical observations are scientifically useful for some types of programs, such as those exploring unknown objects, where a principal investigator must make decisions in real time as data are acquired. In addition, classical observing supports the interaction of the astronomical user community and the Observatory staff, which is valuable. The visiting astronomers better understand Gemini, its processes, and its people, and the Observatory benefits from the visitors' expertise and intellectual contributions. In some cases, returning classical observers may receive enough experience to establish partner astronomers as expert queue observers for the future, and indeed we are considering allowing limited-mode queue observing by visiting classical observers, as a backup option to use the telescope if the originally planned classical program cannot be executed because of weather conditions.

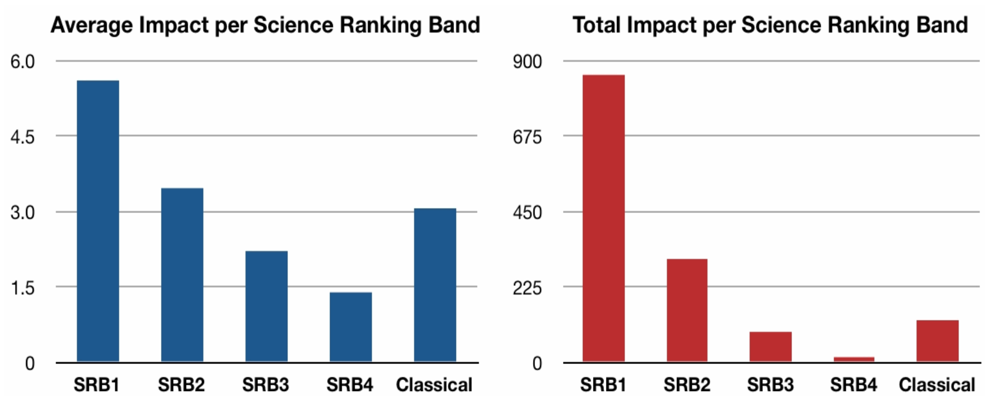


Figure 5-2: Scientific impact of Gemini publications as a function of science ranking band (or classical status).

While classical observing is familiar, Gemini's current queue operations are efficient and effective. With planning, the highest ranked science programs obtain their required time on sky; weather is not the factor that determines successful execution of the programs. The highest ranked programs indeed produce the highest impact publications (Figure 5-2).

Maintaining queue operations is also a way to leverage Gemini's strengths. Currently around 25% of Band 1 programs are targets of opportunity (ToOs), where the observations cannot be planned well in advance. Running a multi-instrument queue means that the full range of observations is generally possible when required. The use of Gemini's ToO capability is expected to grow with new operating facilities (Pan-STaRRS and the Palomar Transient Factory), and LSST would likely further increase the demand. A second great strength is the adaptive optics capabilities, available on both Gemini telescopes. AO observations are only productive in good seeing, and laser AO operation is only possible under clear skies. AO science is therefore demanding, but an operational queue can preferentially deliver the data.

[6] This comparison assumes all of the savings of the proposed streamlined queue+classical operation, with scientist support the first night of each classical run, the majority of classical runs significantly longer than one night, and all data checked for quality before deposit in the Gemini Science Archive.

5.2.2 Small Core Scientific Leadership Team

Reductions in staff throughout the Observatory are essential to fulfill the budget requirements. We must retain a core scientific leadership team, however, even in the face of reductions. The expertise of these active research astronomers is critical to guide the Observatory, to mentor the junior staff, and to interact with our international community. A key group of world-class researchers who use Gemini themselves pushes the Observatory's capabilities, and their experience helps them identify subtle problems and subsequently find solutions. They are able to understand the goals and needs of the partner astronomers, and apply their familiarity with the facilities so the community scientists can be successful.

In addition to the senior leadership team, we will continue to employ Science Fellows, although in significantly diminished numbers. These entry-level positions offer recent PhDs the opportunity to interact with a broad international community and understand (and contribute to) the operations of a modern observatory. The Gemini Fellows also provide a crucial vitality to the Observatory, bringing fresh perspectives to the permanent staff.

Consistent with a smaller science staff size, the telescope time available to the remaining staff will decrease. As of semester 2012A, the staff time allocation has been cut in half, with the remaining observing time redistributed among the non-site partners.

5.2.3 Non-Research Observers

A significant change in Gemini's approach to science operations is to move about 75% of the execution of the queue observing to non-research staff. This change brings significant savings because these staff members are not allocated research time; 100% of their effort is functional work of the Observatory. We will accomplish this by merging our current groups of System Support Associates (SSAs) and Data Analysis Specialists (DASs) into one group and expanding the group slightly. The members of this new Systems Operations Support group are expected to either have technical backgrounds and specific interest in astronomy, as the current SSAs and DASs do, or be PhD astronomers who choose not to pursue research careers. Research astronomers will serve as observers for the remainder of queue operations, primarily to ensure that this staff group retains the familiarity with the instruments and nighttime operations necessary for instrument and user support. Given the similar populations, we expect turnover in the new group to be comparable to that among the existing SSAs. Moreover, we are designing a range of job duties within the Systems Operations Support group in order to allow for real career progression within the broad role.

These non-research observers are being introduced now. Training of some members from the current SSA and DAS groups commenced in 2010 expanded through 2011. We expect that approximately 10% (South) to 25% (North) of the semester 2011B observing effort will be provided by the professional observers. (The lower percentage in the South is due to the heavy commissioning load.) This early training effort will allow the Observatory to evaluate and improve upon the documentation and training procedures for science operations. This will improve consistency of operations and reduce effort associated with staff turnover in the longer term. After training, new staff will be certified before conducting observations on behalf of partner scientists, to ensure quality results. The systems support pool will be expanded from 9 to 10 staff at each site by 2012, and the transition to the final 75% observing coverage is expected by the beginning of 2013.

5.2.4 Making a Successful Transition to New Operations

5.2.4.1 Science Staff Reductions

The long-term budget is sufficient to maintain Gemini's core strengths, but the total scientific staff and non-essential (albeit valuable) functions must be reduced. One important consequence of this plan is the significant reduction of the total research effort within the Observatory, with 2.4 FTE of research effort (shared among 9 positions) eliminated. Research time will be concentrated among fewer individuals, and those people will be able to take up the full allocation of research time appropriate to their posts. Both of these factors work to maximize the return on this investment.

The diminished science staff will be able to support four instruments per site plus laser AO capabilities, consistent with the Engineering staffing. Additional instruments would require duties of an instrument scientist, effort of contact scientists, and software support to maintain more instruments through upgrades of the common Observing Tool.

5.2.4.2 Queue Software Upgrades
A second significant area where human effort must be reduced compared with current operations is in the execution of the queue. We are investing in software to reduce recurring work. In particular, we will put in place better tools for queue planning and better systems to do time accounting without significant manual effort. The plan for developing software begins with the tasks where the saving of effort would be greatest.

Before developing any new software, however, we are currently engaged in defining its essential requirements. The goal is not to replicate the existing queue fully but to offer functionality that achieves the most desired benefits. We have studied other observatory queue systems to define critical functions. Moreover, to manage some of the risks in the timing of software delivery, we are identifying modifications and simplifications to queue operations, accepting some inefficiencies and lack of optimization while maintaining the queue's basic functionality with reduced staffing. Easily-implemented options include reducing data quality checks on poor-weather observations, eliminating formal planning and completion goals for poor conditions, and eliminating backup queue planning during classical observing runs while encouraging astronomers to develop their own backup programs if the primary observations are not possible.

5.2.4.3 Other Software Upgrades
Current data processing efforts include major software development (e.g., to bring IRAF into a PYRAF environment). Such development projects must be completed by the end of the transition. This will be accomplished near-term through an expansion of Gemini's software development team (through fixed-term hires) and through additional contracted effort. All of this points toward a greater need for instrument developers to deliver robust and well-documented software interfaces and data reduction recipes.

Future development in the GSA will proceed in stages. During 2012, a significant upgrade will enable: browser-based downloads, via VOSpace, of new or modified data from a PI's program; more powerful browsing of program contents; Really Simple Syndication (RSS) notifications of the arrival of new data; and improved calibration association. In the longer term, we will investigate merging current GSA capabilities with the Gemini reduction package and recipe system. The goal will be VO-ready reduced data products (of quick-look quality) and in-archive reduction of arbitrary sets of data with variable reduction parameters. This would provide PIs and GSA users with a powerful data assessment capability.

5.2.5 Nominal Science Operations Labor Staffing Model - Summary
The net result preserves many attributes of Gemini's queue system, despite the reduced staffing and reduced expense. The system can match observing programs to changing conditions, optimally use laser AO, provide the community with exceptional ToO capabilities, and systematically complete the highest ranked proposals. Together, this supports the priority to "…*provide a high fraction of queue operations with appropriate data quality control, data products, and completion fraction*."

5.3 Base Facility Operations and Engineering Staffing

A new effort for this five-year period is to enable nighttime operations from the base facilities at both sites. The anticipated scientific gains motivate this move to modernize operations and improve the connection with users, and as a secondary benefit, it will reduce expenses. Fundamentally, base facility operations must proceed in a way that protects the safety of the telescopes, instruments, and personnel. The intended endpoint within this five-year period will have in place redundant automated systems and technical support staff on the summits. During this period, in addition to regular operations and maintenance, Gemini engineering will continue to devote considerable resources in the near-term to complete high priority instrument projects. Specifically, these are GeMS, FLAMINGOS-2, GPI, and GMOS-S CCDs at Cerro Pachón, and GMOS-N CCDs at Mauna Kea.

5.3.1 Base Facility Nighttime Operations – Advantages and Implementation Details

The proposed transition to base facility operations has a number of desirable outcomes. These include:

- Modest but still significant cost reductions, leading to a "return on investment" of a few years and, long term, significant savings (millions of dollars) compared to continuing with Gemini's current operations model;
- Improved working conditions for the night staff through a safer, warmer, and more oxygenated environment and increased safety through reduced travel on mountain roads;
- More comfortable and effective classical observer support, via extensive personnel available at the base facilities ;
- The possibility of extending this model initially through eavesdropping to truly remote operations, with astronomers world-wide participating in queue and classical observing.

Logically, given the timescale for reduced funding and related staff reductions, realizing these long-term benefits requires making this transition while the Observatory still has resources available. In practice this means initiating transition projects amidst near-term strategically important work (instrument activity), and careful management of the entire effort, consistent with Gemini's well-established planning system, will be required. The goal is to complete the base facility project fully; we will further manage risk through contingency planning, including well-defined descope options.

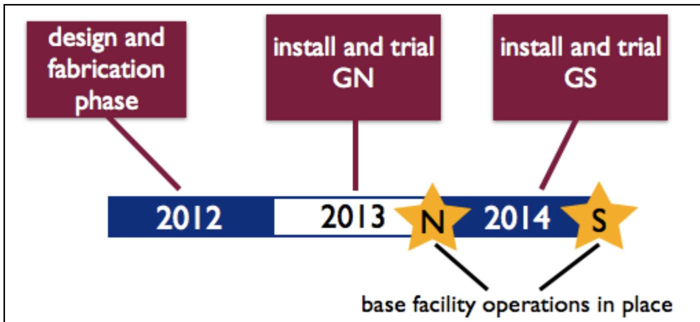


Figure 5-3: The timeline, including key milestones in the transition to base facility operations, are shown in this timeline. Base facility operations are anticipated to be introduced during 2013 and in place by 2014 in this plan, initially at Gemini-North where the benefits are expected to be higher given the harsher conditions on Mauna Kea compared to Cerro Pachón. More seamless day/night staff transitions at the beginning of each shift change, with the possibility of shift changes in the middle of the night for staff.

Figure 5-3 illustrates key milestones through 2014 in the move to base facility operations. The planning phase has effectively already begun, to yield a series of projects that make up this effort over the five-year period. The design phase of this full effort (including remote monitoring systems, telescope modifications, etc.) will nominally be completed by the end of 2012. Scientists and system support staff will provide essential contributions in setting requirements. Each site will have extensive trial periods, during which time science operations will be conducted from the base facilities while full technical support remains on the summits. We will explore long-term options for sharing tech-support with our neighbor observatories on Mauna Kea and Cerro Pachón, many of which are well on the path to remote observing and have a common interest in sharing a nighttime technical support pool as a cost effective means of retaining sufficient presence on the summits. In fact, several Mauna Kea telescopes are already operating in a fully remote mode, with no operators on the summit.

Remote operations are not completely new to Gemini. The Gemini North laser has been operating regularly from the HBF during routine nighttime operations for about a year, giving us confidence in our ability to operate lasers at both sites remotely, if required.

5.3.2 New Acquisition and Guiding (A&G) Project

A core component of our strategy to migrate to base facility operations is to increase overall telescope reliability. While new systems will be in place to remotely monitor and control various observatory subsystems, the most effective means of addressing technical problems that might emerge over the course of a night is to prevent the problem from happening in the first place. Aggressive preventative maintenance, redundancy in key systems, and elimination of reliability obstacles across various systems are keys. Today, one of the sources of unreliability is the A&G units that are in use now at each Gemini site. Gemini's A&G units function as the central nervous system for the entire telescope, which is fully active and requires a steady stream of wave front sensing data to preserve guiding, primary mirror figure, and overall collimation, not to mention guard against wind shake and counter atmospheric tip/tilt aberrations. While the basic design concept used in Gemini's A&Gs is sound (e.g., redundant peripheral guide probes, a highly articulated tertiary mirror, and an acquisition camera with associated high-resolution wavefront sensor), in practice these units have been unreliable in several areas.

In recent years, instead of developing new A&G units, engineering effort has gone into aggressive preventative maintenance which has reduced the down time associated with the A&G's but at the cost of scheduled telescope shutdowns and reduced science time. To avoid further delays in replacing the A&G units, Gemini will no longer treat these as substantially in-house development projects but instead will contract them out, along the lines used for instrumentation (including competitive bidding across the Partnership). Near-term this will still require significant in-house effort to generate all of the technical requirements documents and interface control documents, but overall this approach will accelerate the completion of this important project and minimize the load on Gemini's engineering team. The new A&Gs will be more modest in design than previously proposed, preserving baseline functionality with a premium on system reliability. The definition of requirements started in 2011, with a plan for the procurement to begin in 2012.

5.3.3 Nominal Engineering Labor Staffing Model

Engineering staffing levels will remain roughly fixed through 2012 due to the large number of high priority projects that remain to be completed, particularly new instrumentation. Beyond then, a sustainable staffing model that is consistent with projected budget constraints leads to an estimated 14% reduction in the number of positions in Gemini's engineering team. The decline will occur gradually over a 2–3 year period toward the end of this transition plan.

The anticipated cuts are strategic, preserving essential skills and taking advantage of long-term improvements to optimize sustained operations. Moreover, a key change that will occur over this period is the completion of several in-house development projects. Scaling back to emphasize operations in the future is sustainable from 2015. However, simultaneously closing out multiple major development projects and transforming observatory operations demands investments in personnel and non-labor expenses in the short term. Careful oversight will be required to ensure success with so many variables on our horizon, some of which are unpredictable.

The dominant long term effect of the future staffing plan for Gemini engineering is to reduce the Observatory's margin and capacity to deal with unexpected events in the future. That capacity has been tapped repeatedly over the brief history of the Observatory, ranging from responding to a major earthquake in Hawai‘i to catastrophic instrument damage to GNIRS. Several years ago the GeMS optical bench was delivered incomplete by a commercial company that essentially went out of business, forcing major rework at Gemini that was never planned. Likewise, FLAMINGOS-2 was recently delivered needing significant rework to its science detector, key mechanisms, and vacuum systems. Prior to these instruments, with the shutdown of the Royal Greenwich Observatory, Gemini's coating chambers were delivered incomplete, and unreliable A&G units were delivered during the construction phase of the Observatory, the fallout from which we are still addressing today.

An obvious knock-on effect of the reduced capacity of Gemini's engineering team is their ability to rectify instrumentation or facilities delivered in a poor or incomplete state, considering both hardware and software deficiencies. In the future such projects will likely be terminated without additional resources provided by the Partners to bring them to a successful closure. The Observatory has recently taken significant steps to bolster the management component of its development program, including greater on-site involvement during the design/development phase of instrumentation projects and clear interfaces to our data reduction system to prevent such mishaps. The use of Gemini engineering resources to more proactively engage instrument builders, fundamentally part of the program to deliver new instruments, will likely be a net savings of effort over the long term. For example, the Gemini Project Manager for GPI has relocated to Santa Cruz, California, the instrument team's base, to participate in the extended period of final integration and testing.

Other risk areas that stem from a reduced engineering team include increased telescope down-time, increased time to complete various repairs, and delays of in-house initiatives designed to yield a more robust engineering environment including training, standardization of hardware, software, and procedures. In this environment, management oversight to ensure the correct prioritization of activities (ultimately to serve the scientific needs of the partner communities) will be key.

Finally, we note the possible impact on telescope downtime a reduction in the size of Gemini's engineering team will incur. It is difficult to predict the degree of change or direction for future downtime. Staff reductions will primarily impact development activity within Gemini's engineering program more than daily Operations and Maintenance (O&M work). Near-term that will tend to minimize the impact on downtime but long term it will tend to increase it, as these are in general the engineers who would handle design/development of system upgrades, as older systems become obsolete. Migrating to base facility nighttime operations will introduce additional system monitoring and diagnostic records that should push downtime to lower values. More meticulous monitoring should make it easier to spot and correct subsystem performance issues before they lead to downtime. In general we foresee downtime changing, but not radically, although it is difficult to confidently predict in which direction.

5.3.4 Engineering Summary

Taken together, through the plan summarized in the previous pages, Gemini engineering is aligning resources and skills over the next 5 years in a manner consistent with the stated priorities while maintaining regular operations. Completing strategically important instrument projects will remain the highest priority within the Observatory's development program. We will take advantage of the window available now to begin the transformation to base facility nighttime operations, yielding a lower cost yet still competitive approach to operations that naturally lends to increased community engagement, which is consistent with the Board's priority to "*have the ability to remotely operate the telescopes*".

5.4 Engaging the Gemini Communities

An important cultural shift with Gemini's reorganization is an explicit emphasis on more directly interacting with and responding to the needs of the partner scientific communities. Both high-level management and scientists will participate in this significant activity.

Gemini's operations are distributed, extending to include both observatory sites and National Gemini Offices (NGOs), which are located in each partner country and host site. The NGOs are a critical component of the system that supports users. They are fundamentally part of operations, and proposed changes will strengthen this role.

5.4.1 Formal Lines of Communication

Gemini's governance structure provides several specific paths for the scientific communities to make known their needs from the Observatory. At the highest level, all Partners have membership on the Board, which sets the overarching scope and priorities for the Observatory, within the constraints of the resources they provide. The STAC, similarly populated with representatives according to partner share, provides the scientific and technical expertise to assess both short- and long-term plans. A recent change has been to strengthen the role of this body, now reporting to the Board, which appoints members. The STAC will have a crucial role in defining Gemini's scientific vision.

Previously, the GSC also served as a user committee. A separate Gemini Users' Committee is being established. This committee will concentrate on the short-term functional concerns of users. While the committee reports to the Director, both the Observatory and the NGOs will have important roles in receiving and responding to this user feedback.

5.4.2 Direct Interactions between Gemini and the Partner Communities

The national astronomy and facility meetings offer opportunities for engagement. We plan to participate in national functions regularly, ideally an American Astronomical Society meeting annually and each other Partner at least once every other year. In 2010, for example, the US NGO coordinated a Gemini Town Hall at the January American Astronomical Society meeting. The Observatory participated in a Brazilian workshop on the future of its major facilities (Gemini, SOAR, and OPD). This was a valuable experience, allowing Brazilian astronomers to learn more about Gemini and its future plans, and giving the Observatory better insight into the needs of this community and the role of Gemini in fulfilling them. The Argentine NGO organized a workshop on Gemini, with national representation at all levels, including the relevant funding agency. Observatory scientists presented talks covering both detailed use of existing Gemini facilities and more general talks on capabilities such as AO. We look forward to continuing similar interactions between Gemini and the partner communities in the future.

Instrumentation is crucial to the scientific success of Gemini and the satisfaction of the Partners. The most fundamental needs of the communities are the facility instruments they can use. Planning for new instrumentation offers another means to interact with and respond to the scientific and technical communities of the partnership. Scientific goals fundamentally determine the instrument requirements, and the expertise of the instrument builders is critical to define what is feasible. The instrument builders can also reveal what is both novel and possible.

Direct interaction with astronomers visiting the Observatory remains important. The science operations modes continue to make this feasible, supporting both classical observing and queue visitors. Although the program for long-term visiting scientists will have less financial support in the future, we will continue to host visitors and encourage their contributions to the institutional scientific culture.

5.4.3 Interface through the NGOs

We plan to maintain the distributed support model that includes NGOs working collaboratively with the Observatory to support our broad community. We intend to take further advantage of the relationship between the Observatory and the NGOs to provide a further avenue for user community input. Critically, the NGOs bring knowledge of their user communities to the table. Fundamentally, the NGOs are the local face of Gemini within their respective communities, so Gemini's success depends on these offices functioning. In addition to the NGOs, which have concentrated on representing the immediate needs of their local Gemini users, the Board and STAC formally represent national desires in setting strategic goals and developing long-term plans.

Successful distributed operations require improving integration of and communication between Gemini and the national offices. Together we have identified specific products and information the NGOs require, and these partner staff now contribute to defining the requirements of the systems they rely on, such as the Observing Tool, that are essential to observatory operations and users. We have already identified a number of specific ways the Observatory can better help the NGOs perform their functions. The NGOs require better access to information about changes in instrument performance, a more concerted effort on training, and better-organized, better-documented, and more complete example libraries. These improvements are in progress. Post-observing support of our users is also included: NGOs now have searchable access to the Gemini helpdesk where post-observation problems are solved. The scientific staff meeting includes the NGOs biweekly, and they have access to minutes from the internal meetings that are held on alternate weeks. Moreover, the NGOs remain crucial members of the Operations Working Group, which guides regular operations.

A key role of the NGOs is to help their local astronomers set up their observing plans to be executed on the Gemini telescopes. The Observatory and the NGOs are working to improve this Phase II system, making it easier and less error-prone for PIs to set up programs and for staff to check them. The NGOs and Gemini are also working collaboratively to eliminate duplicated effort, while still providing expertise of contact scientists where necessary. Overall, Gemini is not shifting additional burden to the NGOs. Instead, we are together working to eliminate redundant work, to concentrate NGO effort in their areas of strength, and to improve efficiency of the entire user support process.

We have introduced regular observatory staff visits to the NGOs. For the NGOs, key goals are better understanding of the instrument status, operations, and data reduction procedures. The Observatory will also benefit from better understanding of the NGO operations and concerns. We also continue to encourage NGO staff to visit the Observatory, to be fully engaged in operations over an extended time.

Gemini has engaged in several collaborative projects with individual partner offices, and we plan to continue these efforts. In 2010, the US NGO and the Observatory together organized a Gemini data workshop that was open to the entire Partnership. NGO and observatory staff, including a number of instrument scientists, gave key presentations to help users better understand and work with data from Gemini. The workshop also offered the benefits of interaction between the Observatory and NGO staff, and with some of the expert user community who contributed as presenters. (The primary audience of the workshop was students and postdocs.) We will continue to use this project as a model, replicating it in other partner countries in the future, as the 2011 South American workshop (collectively organized by the NGOs of Argentina, Brazil, and Chile) and the 2011 Australian workshop on a broad range of facilities have already demonstrated. A further positive residual outcome will be the development of basic data reduction cookbooks, including examples, for most of the current instruments and modes. The rough forms of these—presentations and example commands—are available from the Gemini and US NGO websites.

5.4.4 Leveraging Community Expertise

Gemini experts are dispersed throughout the international community. They are skilled observers, sometimes having particular knowledge of the instruments, and they know how to reduce Gemini data to obtain scientifically meaningful results. The Observatory can leverage this expertise, serving as a center for sharing knowledge about Gemini observing, data, and data reduction. We have relationships with some experts, such as those on the Data Reduction Working Group, and we can more actively seek the key contributions of others.

One starting point is to host electronic forums for software contributions. We expect shared software contributions to be valuable, even if they are not fully reliable as the Observatory provided software packages must be. We know that many members of the community use commercial packages (like IDL), and their solutions may help others. Moreover, many people may benefit by having some examples of issues and possible approaches, even if the sample code is not applicable in all situations.

5.4.5 Unifying Gemini Interests within Partner Countries

Under the current Gemini governance and organizational structures, Partner desires for Gemini are conveyed through numerous channels. Community representation on the Board, STAC, Users' Committee, etc., all yield input to the Observatory. We encourage each Partner to develop and deliver a clear and consistent message so Gemini can respond successfully. The scientific communities can be more engaged and have more influence if their paths of communication with Gemini are clear locally. While the various advisory and organizational bodies concentrate on distinct aspects of the Observatory, in combination they describe each partner community's interest in Gemini. The Observatory can best serve the communities if their needs are clear.

Taken together, all these community-related initiatives are intended to deepen the working relationship among the Observatory, NGOs, and ultimately the entire Gemini research community, recognizing the success of each party in this relationship is essential to the scientific legacy we collectively build. Consistent with the priority to "*better interface with the partner community*", we look forward to working with all of Gemini's stakeholders to build that legacy.

5.5 Infrastructure

5.5.1 Energy Solutions

An observatory-wide, cross-discipline energy planning oversight and control group performed an assessment of Gemini's energy use and habits in 2009 in order to identify improvement opportunities and develop a long-range plan for sustainable future operations. The assessment identified behavioral changes and inexpensive energy-conservation solutions that the Observatory is implementing systematically over the next few years. Every opportunity to replace equipment with more energy-efficient units has been identified and replacements are planned in accordance with resource availability, environmental considerations and observatory schedules. The group's study also determined that solar power solutions make economic sense at this time in Hawai‘i, but not in Chile, and then only if accomplished through a third party alternative power purchase agreement rather than through outright direct purchase of the solar panels. We are exploring this alternative now and hope to complete a successful procurement during 2012.

These energy-cost solutions are part of a larger effort devoted to the "greening" of Gemini. Using the U.S. Green Building Council's operation and maintenance guidelines for Leadership in Energy and Environmental Design certification standards for Existing Buildings (LEED-EB), the Administration and Facilities Group studied the feasibility, approximate costs, and expected benefits of seeking LEED certification for the Base Facility buildings. The group's 2010 report concluded that certification should not be pursued as an end in itself due to the manpower and associated costs required to do so. However, they proposed that LEED-EB improvement initiatives be adopted as and when there is a possibility of doing so without prejudicing on-going operations. Future efforts will include incorporating LEED standards in the creation of more comprehensive documentation of facility management policies and procedures, creating and running surveys of water and energy consumption behavior, promoting sustainability initiatives internally, compiling short term and long term data measurement and reporting practices on sustainability-related issues (water, energy, recycling, transport, etc.).

5.5.2 Network Connectivity

The data rates required for science-data generation and delivery are key factors for the technical requirements for network connectivity. There are two important indices that are useful in bounding the Observatory's science-data requirements. They are the:

- Nighttime peak readout rate of the observing instrument detectors, and the
- Daytime sustained 12-hour rate required to move the night's data to the Gemini Science Archive[7].

The nighttime *peak* rates are an index of the internal local-area network (LAN) requirements, while the daytime *sustained* rates are an index of the external wide-area-network (WAN) or Internet requirements. As a rule of thumb, the *nighttime peak* and *daytime sustained* rates are good upper and lower bounds.

The LAN connectivity within both the Gemini North and Gemini South internal complexes are comparable and sufficient. Of course, storage capacity will also require continuous improvement due to both the larger image sizes and transfer rates of the future instruments, as well as the simple accumulation of historical science, engineering, and administrative data. Technically, there is less north/south parity in the available Internet/WAN bandwidth (155 Mbps versus 45 Mbps), due to higher availability and lower cost from the US Mainland to Hawaiʻi than to Chile. However, this is not an operational issue, and if needed, the overseas circuits can grow significantly at moderate cost.

5.6 Possible Program Expansion

While Gemini's program is tailored to meet the demands of a decreasing budget, possibilities for additional partner contributions beyond the baseline budget presented in Section 7 exist in the 2012-2015 timeframe. If additional funding is available, it would be used to provide additional capabilities for the community as well as to reduce risks in the plan presented here. We do not propose to use additional funding to merely avoid implementing our transition plans, recognizing that the lower cost yet still very competitive operations model these changes will bring are in the best interests of the Observatory and community over the long term. Instead we propose to use any additional funding provided to "add value" to the Observatory, while preserving the baseline elements of our transition plans.

For example, one of the most significant changes at Gemini in response to a reduced budget is the Observatory's capacity to support a full complement of instruments. This requires both engineering and science staff, both of which are being sized to support what will be a competitive but still sub-optimal range of instrumentation in a so-called "4+AO" model. The community would doubtless benefit by preserving instrumentation at each site, hence one high priority application for additional funds would be to expand the instrumentation provided at each site to "5+AO". In practice this would mean expanding the science and engineering staff. The exact size of the increase would be linked to the nature of the instrumentation preserved, recognizing that MIR systems (which require a chopping secondary) are significantly more labor intensive to maintain than most optical and near-infrared instruments. Beyond expanding our scientific base, this could also leverage time exchange opportunities, particularly in Chile, where the Japanese community has expressed considerable interest in gaining 8-m access for ALMA follow-up observations.

Beyond mitigating the impact of our instrument decommissioning plans, additional funding could be used to accelerate the development of new instrumentation. Even modest additional funding could be targeted toward detector/controller upgrades, yielding significant performance enhancements in some instruments while reducing maintenance. More significant investments could be used to launch entire new instruments or facilities, like those described in Section 5.1.3. For example, replacing Gemini's aging AO system in Hawaiʻi with a modern GLAO system would require a new adaptive secondary mirror and considerable resources. That possible component of our development program would only be started late in this five-year plan, but the injection of significant funding soon could accelerate that program.

[7] This is a benchmark only. The science data actually are moved to the GSA in near real time.

Finally, another option we would explore would be to rapidly extend the base facility component of our plan to support remote operations via satellite operations centers, for example at the NGO headquarters. Our plan currently extends operations to Hilo and La Serena, with the possibility of eavesdropping for PIs as data are recorded, but additional resources would be required to set up remote operations centers with the necessary network, computer, furnishings, and video-conferencing equipment for classical observing runs to be conducted either off-site or through a combination of visiting astronomers on- and off-site.

Other possibilities exist, but in summary, if additional funding becomes available we propose enhancing the Observatory over the baseline proposed in our transition plans, principally through the instrument program and science operations changes that ultimately will benefit our research community.

5.7 Collaboration with Other Observatories

The US Decadal Survey, *NWNH,* contains numerous references to a possible joint structure between NOAO and Gemini, including

"…NSF…should consider consolidating the National Optical Astronomy Observatory and Gemini under a single operational structure, both to maximize cost-effectiveness and to be more responsive to the needs of the U.S. astronomical community."

The governance structure of Gemini is complex and continues to be a lively discussion topic in many forums. This includes the possibility of consolidating Gemini and NOAO under a single structure. Such a full consolidation would have significant implications for the Gemini international partnership, implications that will undoubtedly be thoroughly explored when discussions begin to craft the post-2015 international agreement.

A single operational structure is not the only option, and many of the desired goals of both *NWNH* and the international partnership could be met in other ways. Gemini strongly endorses the use of inter-observatory collaboration and cooperation to achieve a variety of objectives that benefit various funding agencies, observatories, and communities. In fact Gemini has spearheaded a number of innovative forms of inter-observatory collaboration at both of its sites. While *NWNH* is naturally focused in US interests and articulates objectives in the context of Gemini and NOAO, this is in fact a subset of the various forms of collaboration Gemini has been pursuing since the earliest days of the Observatory. Table 5-1 lists a summary of current and possible future collaborative efforts.

In Hawai‘i, Gemini has played a central role in the well-established inter-observatory time exchange program with Keck and Subaru. This program makes it possible for communities to utilize capabilities that they would otherwise not have access to and helps avoids replication of expensive instrumentation across multiple observatories. It also tends to drive observatories toward a certain degree of specialization to take advantage of unique design features. For example Subaru is currently the only 8–10-m class telescope with extensive built-in prime focus capabilities. Of course Gemini was designed as a high resolution infrared platform and does not have any prime focus capabilities; hence a natural synergy is emerging between these two observatories and communities.

Other examples of collaboration abound, some which save on labor, others on capital investments, while others leverage resources that could not be afforded individually. Between Gemini and Keck, thanks to a joint laser development program sponsored by NSF, our solid state lasers share core technologies which lead to a range of savings. For example Gemini's laser technicians that have been trained in the repair and maintenance of Gemini's lasers can, if necessary, also cover Keck's laser service needs and vice versa, providing crucial backup support. Likewise, Gemini and Keck share a common pool of spare parts for our lasers, reducing our overall costs for laser components. Resource sharing exists in the operation of our lasers too as, for a number of years, a common pool of aircraft spotters were used by Gemini and Keck. Both Keck and Gemini are developing complementary electronic aircraft detection technologies that we expect, when combined, will lead to the Federal Aviation Association's (FAA's) acceptance of a fully automated system, thereby eliminating our significant collective spotter costs. Keck has been crucial in the development of software for inter-observatory "laser traffic control"—the same system that Gemini is installing at Gemini-S—demonstrating how Gemini acts as a bridge not only between Mauna Kea observatories, but between Hawai'ian and Chilean observatories. Another example of this is the Mauna Kea Weather Center (MKWC). Gemini played a central role in the coordination of resources at the National Weather Service, University of Hawai'i, Subaru Observatory, and ultimately all of the Mauna Kea Observatories who now co-fund the MKWC.

Hawai'i Based Inter-Observatory Collaboration

- Between Keck and Gemini –
  - Shared spare parts pool for Keck and Gemini lasers
  - Mutual backup technical support of LMCT solid state lasers
  - Coordination of aircraft avoidance systems
- Common use of laser traffic control system (LTCS) across entire summit
- Shared use of advanced summit monitoring systems (seeing monitor, weather, etc.)
- Mauna Kea Weather Center
- *Common technical support team on MK to support base facility operations*
- Mauna Kea Support Services
- Coordinating instrumentation –
  - *Fiber feed from Gemini to feed CFHT high-res optical spectrometer*
  - Gemini/Subaru collaboration in developing WFMOS
- Gemini, Keck, Subaru telescope time exchange program

Chile Based Inter-Observatory Collaboration

- Shared NOAO-S machine shop
- Shared laser milling machine (SOAR/Gemini)
- Gemini provides advanced coating technology to SOAR
- AURA Lecture Hall
- The Cerro Pachón restaurant & dormitory
- AURA Library services
- *Common technical support team on CP to support base facility operations*
- NOAO-S Administration and Facilities support services
- Shared Recinto infrastructure
- Laser Traffic Control System
- *Gemini's travel support services*
- *Information Systems*
- *Human Resources services for Chile-based international staff, including visas required from the United States*
- *Weather forecasting and site monitoring*
- *Common mountain transport contracts*

Table 5-1: Current and prospective future (italicized) areas of inter-observatory collaboration.

In Chile, comparable levels of inter-observatory collaboration exist between CTIO, SOAR, and Gemini. For example SOAR does not have a coating chamber – a cost saving decision that was enabled by the investment and capabilities in coatings that are unique to Gemini, where sputtering technology is used. In 2009, the SOAR primary was aluminized in the Gemini coating chamber before it was reconfigured with the various magnetrons required to apply a 4-layer silver coating on Gemini's primary mirror in 2010. Sharing such facilities has many other benefits. For example, Gemini has benefited from the well-outfitted CTIO machine shop for many years. Having this capability on-site allows Gemini's engineers to work with other AURA facilities and eliminates the need for Gemini to invest in expensive machining equipment. The AURA lecture hall, which is attached to Gemini's Southern Base Facility, was co-funded by Gemini and CTIO so that any of the AURA observatories have a modern and spacious venue for lectures and meetings. Finally, in Hawai'i the Mauna Kea Support Services and in Chile NOAO South Administration and Facilities provide absolutely essential functions that benefit Gemini's operations including road maintenance, snow clearing, power and communications, emergency medical support, mid-level housing for night staff, and food services for all observatory staff.

In 2011, an AURA initiative to centralize some common NOAO and Gemini administrative functions was launched. Initially this will involve consolidating in Tucson many of the procurement functions that are currently distributed between Tucson and Hawaii.

In the future, Gemini seeks to further its tradition of reaching out to our neighboring observatories in ever more innovative manners. To support our base facility operations plans we will work with our neighboring observatories to fund and train a common pool of technical support that will be cross-trained in essential support functions across all observatories on Mauna Kea and Cerro Pachón participating in the program. This will leave the telescopes with hands-on support if/when needed without the cost of replicating this capability across multiple facilities. Gemini is also the only AURA Center with a travel office staffed by a licensed travel agent. Given its sub-critical staff size, which demands that staff travel North/South to sustain operations across the entire observatory, Gemini took this step to decrease our costs (eliminating commissions and identifying lower cost airfares) and we stand ready to explore the use of this unique capability across AURA to extend these savings to other AURA Centers.

These and many other examples demonstrate how Gemini embraces the philosophy of inter-observatory cooperation and collaboration inherent within the US Decadal Survey's recommendation[8]. While collaboration with NOAO has special relevance to maximize the benefits of investments the NSF makes, we take that call for increased collaboration and extend it much farther. Gemini's international nature has driven the building of bridges between and across the summits of Cerro Pachón, Cerro Tololo, and Mauna Kea. Perhaps no other observatory is better poised than Gemini to "maximize cost effectiveness" through efficient mechanisms, find synergies between independent observatories, and avoid the cost and complexity of the major restructuring sometimes associated with such savings.

5.8 Overview of Future Work and Observatory Transformation to 2015

This future plan for Gemini Observatory has two key elements: instrument development and ongoing operations. The budget for instrumentation is protected, and will not be used to make up for the reduction in operations and maintenance. Continuing instrument development is essential to maintain Gemini as a leading observatory, and many options for new capabilities leverage the existing facility and Gemini's inherent strengths. The central issues are to enhance the mechanism for instrument selection to result in a comprehensive suite that fulfills community priorities, to improve the procurement process, and to help develop collaboration across the Partnership.

Operations must be transformed to accommodate the anticipated budget. The most significant spending cuts come from reduced staff size. Some of the labor loss is replaced with improved tools and increased efficiency. The extended timescale of the transition allows us to spend up-front to develop and implement these tools and processes. Less internal support (administrative services or information systems, for example) is a natural consequence of reducing the scope of the Observatory's work. Other areas correspond to diminished activity or output. For example, both net research and the total engineering effort for development projects are significantly reduced.

We are also significantly reducing non-labor budget. The greatest reductions are in the category of Supplies and Materials, trimming spending on spares, and implementing sharing arrangements where appropriate (e.g., sharing laser spares with Keck). We plan no coatings of either primary mirror during this period. Extending the replacement cycle on computer equipment and diminishing purchases of general supplies across the Observatory account for the remainder of supplies and materials changes. Reducing planned development work performed in-house results in lower costs for subcontracts and

[8] The Gemini Board will explore the suggested structural changes in the near future in the context of revising Gemini's governance.

general equipment. Extending the replacement cycle on vehicles is also significant in the latter category. We are reducing Travel across the Observatory. Within Science Operations, some of the decline is a consequence of reducing the number of PhD personnel and their corresponding research travel. The greatest contributions to the reduction in Purchased Services are midlevel food and lodging, summit shuttle services, warehouse rental, and cell phone expenses, with the first two of these a direct consequence of base facility operations.

The experience of the Observatory establishes a solid foundation for continuing operations. We do not need to invent everything *ab initio*, although some aspects, such as queue observing, must be implemented differently. Building on this base, we can maintain world-class international facilities, support classical and queue observing, and offer laser AO and optical and IR imaging and spectroscopy in both hemispheres. However, we will not deliver everything we had in the past. Some specific changes that this plan introduces are:

- Offer 4 instruments and AO at each site
- Reduce research effort
- Reduce training of the next generation of scientists, having fewer Gemini Fellows
- Limit support for new data reduction software and procedures
- Limit support for rapid ToO observations during classical runs
- Reduce staff opportunities to lead innovative projects
- Reduce in-house development activities
- Require that delivered instruments be high quality and robust
- Reduce margin to respond to unexpected events

Having evaluated the possible trades, we conclude that the effort and investment we propose to make in the near future will leave Gemini sustainable over the long-term, and do so while fulfilling our core goals.

6. Broader Impacts

Gemini has a keen sense of responsibility, not only to disseminate the acquired science knowledge to the broadest and most diverse audiences possible, but also to build a highly diverse staff who will perform all of the activities required to achieve the acquisition of this knowledge. We further aim to encourage new generations of diverse people to consider careers in astronomy and other science, technology, engineering, and mathematics (STEM) pursuits.

The general public has a natural attraction to, and engagement with, modern astronomy. This fascination probably arises from astronomy's innate connection to some of humankind's oldest and most profound questions, including: "Where did I come from, where am I now, and where am I going?" Even general audiences are eager to hear about the discoveries and knowledge resulting from use of Gemini. The Observatory has been successful at sharing this knowledge with groups at many levels of understanding. Gemini's Public Information and Outreach (PIO) group concentrates on these efforts to engage the public directly, so they benefit from the investment in the research infrastructure the Observatory as a whole represents.

6.1 Broadening Participation of Underrepresented Groups

6.1.1 Gemini Workforce

Gemini's efforts to broaden participation of underrepresented groups start with its hiring practices, where the Observatory has the most control and the most direct influence. However, it is important to note that Gemini is unusual among NSF-supported observatories in that it has no facilities located within the continental United States*,* more than one-third of its funding comes from partner countries other than the United States, and the international Partners expect workforce representation from their respective countries. Nevertheless, and with the further challenge of operational locations in relatively remote, small, and isolated communities, Gemini is an enthusiastic participant in the AURA program to broaden participation and historically has done an excellent job of recruiting a workforce that is diverse, especially with respect to gender and race.

Currently 33% of Gemini's Ph.D. scientists are female, which is over twice the national pool average, with half of the tenured scientific staff (of four) female. Female representation in the engineering occupations presents the greatest challenge for Gemini; locating and hiring women in the engineering fields continues to be difficult. Unfortunately, the national pool is small, and the local pools are even smaller. Gemini faces the added difficulty of luring engineers to areas that are geographically remote (Hilo and La Serena), where spouses or unmarried partners have difficulty finding employment (or may be forbidden to work, if on a visa), and families with children may have schooling issues. Nevertheless, Gemini will continue to strive to improve gender balance in all areas.

6.1.1.1 Ongoing and Future Enhancements - Recruiting

There are three key target areas (in the US) for improvement attracting and retaining:

- Female engineers,
- Black or African American astronomers and engineers, and
- Local hires in Hawaiʻi in general and STEM occupations.

To pursue these goals, Gemini, supported by AURA, will work to develop:

- Workforce pipeline initiatives, such as internships and community outreach programs, that are targeted to reach individuals from underrepresented groups to either provide early exposure to astronomy related careers or to provide related experience when they are at the threshold of their careers;

- Recruitment processes and practices that are designed to increase penetration into a pool of applicants from underrepresented groups. For example:
  - In the US, develop relationships through the US NGO (NOAO Gemini Science Center) with organizations such as the Society of Women Engineers, the National Society of Black Physicists, the National Society of Black Engineers, and in historically minority colleges and universities. We are already working with the Fisk Vanderbilt Bridge program to provide internships with underrepresented minority students.
  - Develop Human Resources recruiting contacts in these organizations in order to broaden the pipeline of candidates. This service could be provided to all Gemini partner countries,
  - Send Gemini scientist and engineer role-model staff members from underrepresented groups to participate in selected meetings and conferences sponsored by these organizations, and to participate in job fairs in Gemini partner countries when invited by the National Gemini Offices, and
  - Develop stronger, more proactive relationships with the University of Hawai‘i, both in Hilo and Manoa (Oahu), as well as the Hawai‘i Community College (Hilo) to build a bridge to Observatory careers. Gemini can collaborate with such work already begun by the County of Hawaii's Workforce Investment Board.

Improved training and preparation for hiring committees will ensure that they understand Gemini's broadening participation goals and are aware of unconscious assumptions or biases and their influence on candidate evaluation. Understanding these biases, they can be mitigated, through a focus on objective selection criteria, and continued broad-based gender and ethnicity representation throughout the selection process.

Improved retention initiatives ensure that once workers arrive, they walk into a workplace that is welcoming to individuals with different backgrounds and experiences. While Gemini has always done a good job creating such an environment, the Observatory is eager to continue to improve. The scope of the augmented employee retention program extends over multiple years. Elements of this program are likely to include: improved family-friendly policies and flexible working schedules; flexible benefits program; a new-hire buddy program; recruitment process enhancements to ensure that recruits get a realistic job preview; increased inclusion of personal-development plans as a part of performance reviews; and other elements to improve employee engagement, and supervisory and management skills. The staff mentoring program (described elsewhere) is another component of the retention program.

Measuring Progress: Gemini will measure the effectiveness of these recruitment and retention activities by tracking over time participation in community outreach programs, demographic data for interns, recruitment application pools, applicants who meet minimum qualifications for advertised positions, applicants interviewed and personnel hired, overall workforce profile, and the resulting employee retention. The Gemini senior management team and the AOC-G are accountable for reviewing the progress of these initiatives.

6.2 Outreach to the Larger Community

The development of the next generation of scientists and engineers is closely related to the workforce issues. Though not exclusively targeting underrepresented groups, an important element of Gemini's educational outreach program is properly focused on exposing young people to the excitement and possibilities of science and technology, and to career options in these areas. This effort will remain broadly based, while continuing to include focused efforts targeting underrepresented groups.

6.2.1.1 Current Status

The Gemini Partnership has directed that the individual national agencies within the Partnership are to be responsible for direct outreach within their countries, including the US. In this context, the Gemini Observatory plays only a supporting role for the Partners' national programs. Notwithstanding, the Partnership has reserved the direct, hands-on outreach efforts in the two Gemini host communities (the Island of Hawai'i and the environs of La Serena Chile) to the Observatory itself, which is pursued through the Public Information and Outreach (PIO) programs. (For an overview of all Gemini PIO programs, see www.gemini.edu/pio/.)

Figure 6-1: Hawai'i island student builds a GalileoScope as part of a student "Summer Fun" program in Hawai'i. Galileoscopes were distributed over 300 telescopes to local students and teachers in workshops that taught optics and the use of the telescopes on the night sky. A similar effort at Gemini South distributed over 40 GalileoScopes to local educators and students in Chile.

Gemini has a long history of outreach into these very diverse local communities, and has established a very strong and effective foundation of community partnerships to leverage the NSF- and Partner-funded resources. These involve a broad cross section of other Federally supported programs, state and local government entities, other local observatories, a variety of local and national not-for-profits, astronomy and cultural museums, institutions of higher learning (including Minority Serving Institutions), and for-profit businesses. These include: the Hawai'i Department of Education, Chilean Ministry of Education, all of the Mauna Kea Observatories, the Cerro Tololo Inter-American Observatory and other Chile-based observatories, the Center for Adaptive Optics, the Astronomical Society of the Pacific, local universities and community colleges, 'Imiloa Astronomy Education Center, small community observatories in the La Serena region, local Chambers of Commerce and economic development agencies, various civic groups, and local businesses including museums, newspapers, radio/TV stations, shopping malls, banking and supermarket chains, and even an automobile dealership.

We have a strong coordinated approach to K-12 STEM training, including teacher training, aimed at opening the eyes of children to the possibilities of life in the high-tech era. The PIO group provides classroom and community presentations and facilities tours on a routine basis, and several principal recurring programs that have more formal and targeted objectives. Collectively, all these programs have an annual in-person audience of about 30,000 people. We describe the primary programs here.

Journey Through The Universe[9]– This flagship annual nine-day education program led by Gemini staff engages the entire East-Hawai'i community, involving students, teachers, families, and the public at-large with an intensive week of educational activities that include: teacher workshops, classroom visits by astronomy researchers, public programs and lectures, and family science nights. In 2010 the program engaged 35 astronomy educators from Hawai'i and beyond who made presentations in 286 K-12 classrooms in 17 schools, directly touching more than 5,600 students and over 100 teachers, and the public programs reached over 3,500 more people. The teacher workshops provide classroom-ready curriculum materials and training, in support of teaching astronomy concepts addressed in the Hawai'i State Standards. As a key element, there is also a Master Teacher workshop that prepares existing

[9] www.gemini.edu/journey

teachers to carry on the training of *other teachers*, in order to facilitate self-sustaining STEM teacher training within the school systems. In 2010 the program integrated the International Year of Astronomy's GalileoScope and was the recipient of over 500 GalileoScopes (from the Ric and Jean Edelman Foundation) that were broadly disseminated through teacher and student training sessions and through the Family Astro Program (Figure 6-1). In 2011 a scaled pilot version of Journey through the Universe was introduced into the Gemini South outreach programming. It is planned to become an integral, and growing, part of the Gemini South outreach programming in future years.

AstroDay Chile[10] - This annual public event is led by the Gemini South outreach group and engages dozens of local Chilean astronomy-research organizations in a day of fun interactive activities, public events, and family learning. The 2010 AstroDay Chile attracted more than 2,000 persons, as well as 17 community and institutional partners including the European Southern Observatory, CTIO, several local businesses and government offices, and visitors from Brazil, Argentina and Colombia.

Figure 6-2: Activities include the very popular StarLab planetarium presentations in Chile and Hawai'I (center) along with AstroDay Chile (top).

StarLab Portable Planetaria[11] – The four Gemini StarLab portable planetaria (Figure 6-2, center) provide in-school and community educational programming on astronomy, navigation, light pollution, and the cultural connections between the naked-eye sky and the host communities in Chile and Hawai'i. In a given year, the StarLabs at Gemini North and South typically visit over 10,000 school children and families. Gemini North schools have borrowed the equipment as part of a teacher-training program for curriculum integration. In August 2009 StarLab was even presented in some 30 sessions to over 700 students in Rapa Nui (Easter Island), a total of more than 25% of the student population on this easternmost Polynesian island.

FamilyAstro[12] – Gemini's version of the Astronomical Society of the Pacific's FamilyAstro program brings local families together in a friendly, safe, and engaging learning environment in both Hawai'i and Chile. Gemini North is recognized as the flagship US FamilyAstro site. In 2010, 7 schools held programs that reached over 300 students and parents.

Live From Gemini[13] – This program provides a classroom full of students a live virtual visit to one of the Gemini Control rooms, where they hear about recent discoveries, learn what it is like to work on the front-line of scientific research, and can ask questions of an astronomer. This program impacts all of the Gemini Partners, with recent programming that included students from Australia who participated in a

[10] www.gemini.edu/node/280
[11] English: www.gemini.edu/node/11263; Spanish: www.gemini.edu/node/11284
[12] www.gemini.edu/node/11251
[13] www.gemini.edu/node/132

nation-wide student-imaging program with Gemini. We are developing a Spanish–language version of this program for delivery from the Gemini South control room.

Gemini Virtual Tour[14] – The Gemini Virtual Tour is an interactive CD-ROM that allows anyone with a computer to explore the science and facilities of the Gemini Observatory. An interactive walk-around of the Observatory and an observation activity using real data and procedures allow users to explore the Observatory in an exciting, educational virtual environment. Elements from the CD-ROM version are now being integrated for web-delivery as CD-ROM distribution is phased out.

Reaching the Parents – While not really a program, but more a programmatic focus, another critical element in effectively reaching K-12 students—especially from underrepresented groups—is the need to *also engage the parents*, who may otherwise have little appreciation of the opportunities available to their children. Gemini's family-centered programs, like FamilyAstro, AstroDay Chile, and AstroDay in Hawai'i provide models for effective informal education that intrinsically draw parents into the students' activity. In the process, parents themselves are also drawn into contact with the adult teachers and facilitators, who can reinforce the possibilities that astronomy and other STEM careers can have for the children.

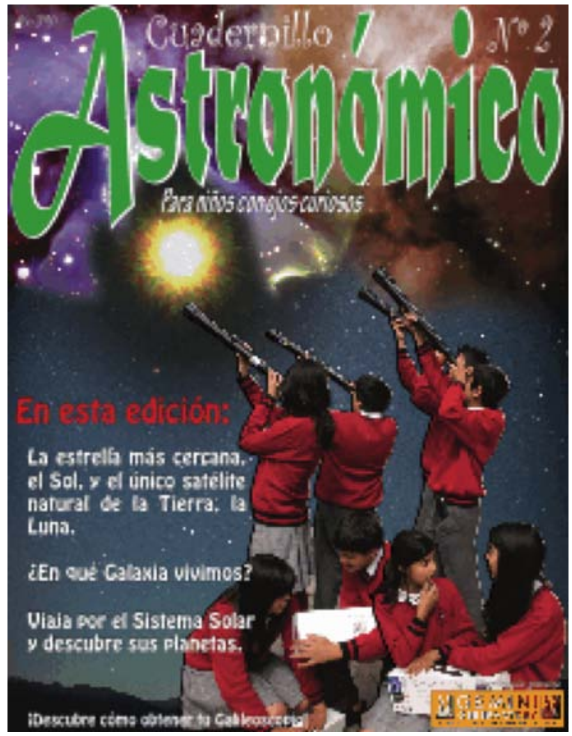


Figure 6-3: Second edition of the Spanish-language publication *Cuadernillo* produced by the Gemini South outreach office for students, teachers and parents.

6.2.1.2 Ongoing and Future Enhancements

The geographical areas that the Observatory directly serves are intrinsically diverse, and current and future programmatic developments have been and will be shaped to meet the need to engage these varied audiences. The Observatory will focus on increasing the penetration into these communities.

Increased Visibility – The PIO program will work arm-in-arm with the Gemini Diversity Advocate to find ways to further increase its reach into the underrepresented and underserved segments of the local communities, in part by being even more effectively proactive in making those communities aware of the opportunities to participate in these programs. The expertise, insights, and attention of the Diversity Advocate will enable and empower more effective ways of communicating the availability and attractiveness of Gemini's programs; strategies to improve access to underrepresented and underserved groups; and improvements in program presentation and content in view of the audiences.

Expanding the Reach – Another aspect of the plan is to make the programs more broadly available on a geographic basis. Many of the more innovative programs have been first developed and tested in Hawai'i, before systematically migrating the fine-tuned versions to Chile, such as the Journey through the Universe, described above.

While direct interaction has focused on the La Serena area, Gemini's Spanish-language publication *Cuadernillo* provides students, teachers, and parents throughout Chile with educational activities,

[14] www.gemini.edu/vtbeta

information, and resources. In 2010, over 5,000 copies of the second edition were printed and are still being distributed (Figure 6-3). A project over the next five years is to develop the subsequent editions.

Visible Role Models – People from underrepresented groups are more disposed to consider associating with a particular activity when they notice that other people from their own group have important roles in that activity. Gemini will focus on ensuring role models from its already diverse staff are even more visible to the public—to spark the realization that "people like me *really* do these things." In the local communities, Gemini staff members participate in various community education events throughout the year, which provides a ready opportunity for them to be role models for people who may never have considered a career in astronomy, science, or engineering.

6.3 Advancing Discovery and Understanding While Promoting Teaching, Training, and Learning

Gemini's purpose statement, "Exploring the Universe, Sharing its Wonders", sends a clear message that advancing discovery and understanding is its reason for existing. At the same time, it is equally important to the Observatory to continue to promote teaching, training, and learning for the Gemini workforce, the greater astronomy community, and the general public, including tomorrow's astronomers and engineers.

6.3.1 Student Internships

For many years, Gemini has focused on the training of the next generation of scientists, engineers, and other occupations found in the Observatory by providing internship opportunities for students (high school, undergraduate, and graduate) from the local communities of Hawai'i and Chile, and the Partnership at large. The science, engineering, administrative, PIO, and safety groups at both telescopes participate in this program. The current internship effort has two components: a wholly internal "Gemini" program, and Gemini's active participation in larger internship collaborations. Recent statistics are summarized in Table 6-3.

Internal internship activities have relied largely on ad hoc individual staff or partner-country initiatives, rather than formal programs. While successful, both the program and breath of representation will be improved by setting up expectations and goals in the annual observatory-wide planning effort. While not expanding the *scope* of the program, the more formal approach will allow Gemini to promote the effort, publicize the dates and slots available, and broaden participation by targeting underrepresented groups.

Gemini also has been able to leverage its resources by opening its doors to a number of larger and more formal programs. In Hawai'i, Gemini is an ongoing participant in the Akamai[15] Observatory program,. This mentorship program for Hawai'i undergraduates is focused on research and its related technologies. For the last four years, Gemini has matched each intern with a mentor and they have been integrated as members of the mentor's group. In the past 12 months alone, three Akamai interns have worked with Gemini staff on projects that have included intelligent version-control software, evaluation of local seeing data, and researching upgrades to the wave-plate rotator used in the sophisticated laser-guide star-system at Gemini North.

The Huiana[16] internship program is another important Hawai'i collaboration. This program is directed at high school students and has a broader scope of employment fields. Huiana is a partnership of several community organizations, including the County of Hawai'i Workforce Development Board, the Hawai'i Island Economic Development Board, Hawai'i Community College, and a number of local businesses. Since 2007, Gemini staff members have mentored Huiana interns who have worked a minimum of 60 hours in such areas as human resources and information systems.

[15] Hawai'ian for: smart, well informed, clever.
[16] Hawai'ian for: group that surveys (what's available).

Number of Gemini Interns		
Year	Gemini North	Gemini South
2006	5	11
2007	7	11
2008	1	19
2009	8	20
2010	12	17
Total	34	78

Interns, 2006 - 2010	
Area of Experience	Number
Science	45
Administration	7
Engineering	42
PIO/Safety	18
Total	112

Interns, 2006 - 2010	
Country of Origin	Number
Australia	12
Canada	16
Chile	53
France	1
USA	28
Venezuela	1
Italy	1

Table 6-3: Intern Participation

In Chile, Gemini has partnered with the CTIO since 2001 to actively participate in their NSF-funded Research Experiences for Undergraduates program and its Chilean equivalent Práctica de Investigación en Astronomía. Each summer, Gemini hosts about 12 student interns, six from each program, and several Gemini astronomers serve as their mentors.

Gemini has also collaborated with the University of La Serena since 2003 to support interns in the Public Information and Outreach Office (12 as of 2010). In addition, each summer Gemini South hosts multiple student interns in several technical fields, including engineering and instrumentation, from across Chile and such Gemini Partner countries as Canada and Australia. Other internship partners in Chile include the Universidad Santa Maria, Universidad Católica de Valparaiso, Universidad Católica de Chile, the La Serena INACAP trade school, and the Universidad de Chile. Gemini will continue its collaborations with these universities and the science agencies in the Partner countries.

The Observatory will expand the intern recruitment scope to include organizations such as the Society of Women Engineers, the National Society of Black Physicists, the National Society of Black Engineers, and to specific historically minority colleges and universities. During 2010 Gemini has built a relationship through AURA with the Fisk Vanderbilt PhD Bridge program. Gemini's first student from the program is now pursuing a Ph.D. This partnership will be developed further over the coming years.

6.3.2 Formal and Informal Staff Training

Gemini has had a broad system of support for staff professional development from its inception. This includes a formal tuition-reimbursement policy, encouragement and sponsorship of career-appropriate professional training workshops, in-house training program, and participation in professional societies and conferences. The Observatory will continue to encourage this participation, and in addition, it will target the further development of formal mentoring programs in the upcoming 5-year period.

6.3.3 General Staff Mentoring

Gemini already has informal mentoring arrangements in place, both internal and external to Gemini. In order to fully realize the benefits of staff mentoring for all disciplines, Gemini is developing a formal program to ensure consistent approaches to training and other applications. The goal is to create a mentorship program that will provide a nurturing learning and support process for all staff, especially postdoctoral researchers, new hires, and new managers and supervisors.

Fully developing this mentorship effort will be a multi-year project. The Observatory began with a pilot program in 2010, taking advantage of an existing link with the Hawai'i Department of Education (Gemini's partner in several joint education projects) and the International Mentoring Association. The program provides training for mentors and mentees, which includes active exercises to develop skills. With the one-on-one mentoring teams in place and meeting regularly, group follow-up activities have occurred quarterly. We continue to evaluate the pilot program.

Gemini has a particular obligation to encourage the professional development of its early-career postdoctoral research staff. The experience and support of the more senior staff helps develop this latest generation of scientists, and also enhances research productivity. Gemini began developing a mentoring program for junior science staff, including the Gemini Science Fellows, in 2007. Within the context of the Observatory-wide mentoring, the postdoctoral mentoring addresses specific research concerns. For example, mentors review and comment on draft publications and observing-time proposals, and provide general advice on research matters including collaboration processes and ethics. A senior staff astronomer acts as an overall mentoring coordinator to ensure consistency, and to develop a deeper body of knowledge from a variety of mentors to address common concerns.

6.3.4 Educational Materials

The PIO effort supports the Gemini partner countries with educational images, videos, brochures, conference participation, and timely updates of scientific results[17]. This work will continue over the next few years. However, to have a lasting impact, the efforts to share science findings and technology achievements must be linked to the enhancement of educational infrastructure in the geographical areas directly touched by the Observatory. Thus, the development of teacher training and materials, human networking, and physical infrastructure for education is inextricably tied to the core Gemini outreach program (described further in Section 6.2).

6.4 Enhancing Research Infrastructure

The initial and ongoing development of the Gemini Observatory is a major contribution to basic astronomy research infrastructure. As detailed in the earlier sections of this document, it has included the development, construction, and operation of major, world-class research facilities. Beyond just the IR-optimized telescopes themselves, these include key roles in the theoretical and technological development of multi-conjugate adaptive optics (AO), solid-state laser guide-star AO systems, and ground-layer AO; supporting significant advancements in detector technology; major breakthroughs in mirror silver-coating technology; major advancements in near- and mid-infrared spectroscopy and imaging; and the development of important science operational technologies, such a nod and shuffle, queue-based Target of Opportunity (ToO) and Rapid ToO observing systems, and efficient planned queue-mode operational process.

The Observatory facilities fundamentally enable groundbreaking scientific progress. The 8- to 10-meter class of telescopes is the largest now operating to obtain optical and infrared measurements. These large apertures are key for providing the sensitivity needed to collect light from faint and distant objects. The large apertures also directly translate into improved spatial resolution, which absolutely cannot be achieved with smaller telescopes. Moreover, Gemini's design and operation, including significant development of adaptive optics techniques, further leverage this foundation to deliver exceptionally good image quality. Gemini currently represents the greatest amount of time available to the entire US scientific community on large telescopes, and the planned future activities would maintain this availability. Temporary agreements with non-federally-funded facilities augment this access, but these arrangements cannot provide stability over the long term, and the absolute amount of available time is limited.

The Gemini Partnership is itself an international collaboration, demanding scientific and technical programs that are truly competitive at an international level. Research collaboration within the Partnership is encouraged, and the global network of members produces rich returns. Collaboration is especially common for the large programs that often result in groundbreaking discoveries.

[17] See examples at www.gemini.edu/pio/#education_outreach.

In more detail, collaboration—beyond the Partnership—has been an important aspect of these accomplishments. Gemini partnered with Keck, the Center for Adaptive Optics, and the US Air Force to develop high-powered solid-state lasers suitable for common use in laser-guide-star AO systems. Gemini and Keck have joined forces through a single contract with Lockheed Martin Coherent Technologies to procure two groundbreaking solid-state lasers for their adaptive optics programs, a 50-W laser for the Gemini-South AO system and a 20-W laser for Keck I.

Gemini partnered with the University of Hawai‘i to initially bring Internet2 to all of the Big Island observatories and, subsequently, to enhance network infrastructure further. Similarly, in Chile Gemini partnered with CTIO and Florida International University to provide high-speed Internet2 access to Gemini South and all the other La-Serena-based AURA observatories, and made it available to the Carnegie Institution astronomy facilities at Las Campanas. These developments have had a substantial positive impact on the research and educational infrastructure for these important, though remote, astronomical sites, and these collaborations continue today.

6.5 Broad Dissemination to Enhance Science and Technology Understanding

The National Gemini Offices of the individual Partners are generally responsible for direct contact with the media in their respective countries. The Observatory’s role is to serve as a resource to the national program offices by coordinating press releases, providing press kits, and alerting them to events of interest to their respective programs – including organizing annual face-to-face meetings with the key outreach representatives from all of the Gemini Partner countries.

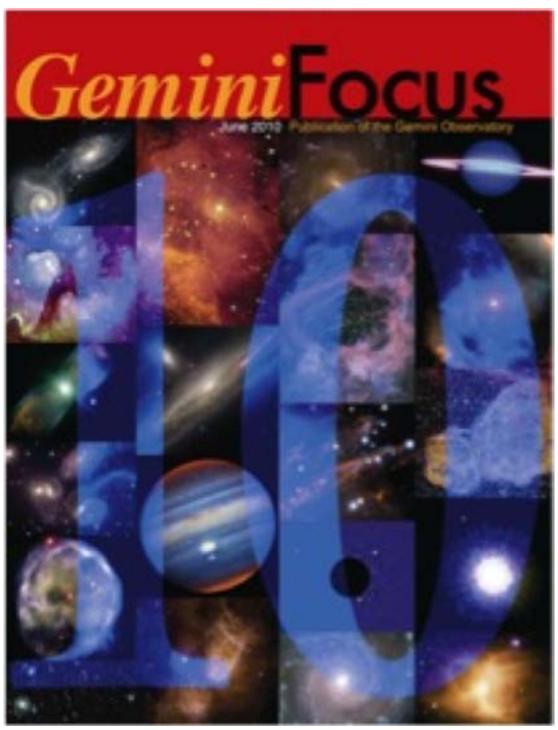


Figure 6-4: *Gemini*Focus, Gemini’s twice-annual newsletter, celebrated the Observatory’s tenth year of science in 2010 with a special 112-page issue highlighting Gemini’s first decade of accomplishments.

6.5.1 Media and Communications

Gemini has established excellent relationships with US electronic and print media and with science publications worldwide. The regular distribution of Gemini press releases to this network has resulted in the broad dissemination of news stories in local, regional, national print and electronic media, as well as numerous articles in popular science, technology, and educational publications.

Supporting the entire Gemini international partnership in “getting the word out” to diverse audiences, ranging from funding agencies to the scientific users and the general public, is a core PIO activity that has has matured over the last fiew years. Representative of this is the growth and evolution of the twice-annual *Gemini*Focus newsletter[18], which, in June of 2010, was the focal-point for the celebration of Gemini’s 10^{th} year of science operations. A special 112-page issue of *Gemini*Focus (Figure 6-4) brought the story of Gemini’s success over the past 10 years to a broad audience with over 5000 copies distributed worldwide. Over the past five years, this publication has become a dynamic and innovative “magazine” that not only puts a human face on the organization but also provides timely and in-depth science articles that target a diverse audience from non-specialist scientists to educators and the science-literate public.

[18] www.gemini.edu/node/27

Complementing the significant efforts involved in producing *Gemini*Focus, current news and updates are continuously provided as "webfeatures" on the Gemini webpage, with typically 30 stories produced each year. Collectively, these pages have amassed over 500,000 hits during the most recent two-year period and have become the de-facto source of current information on science produced with the Gemini telescopes and activities at the Observatory for its communities and the public/media at large.

6.5.2 Media Resource Center

Gemini's full-service media resource center produces regular press releases, and provides an extensive library of images and broadcast quality videos. The current web-accessible image and video library has over a dozen broadcast-quality video clips, many in high-definition format, and over 200 publication/high-quality images, diagrams, and illustrations, including all the Gemini Legacy imaging program images. These are being used in many posters, outreach publications, magazines, and books, as well as documentary movies/videos on astronomy produced by others. About 10,000 CDs and DVDs are distributed locally and across the Partnership yearly.

Figure 6-5: Webpage and "new media" (such as WWT) are a part of Gemini's exploitation of new, popular, and sophisticated web information delivery.

Current "New Media" include such resources and products for Facebook, Microsoft's World-Wide Telescope, GoogleSky, and other interactive web-based media. PIO has already entered this realm with a tour of Gemini Legacy Images on the World-Wide Telescope (Figure 6-5) and web adaptations of several modules from the popular Gemini Virtual Tour CD-ROM. In addition, several new podcasts have been produced that highlight such topics as the integration of the Gemini South laser, mirror coating and other topics related to technological milestones at the Observatory. As new media technologies and content will certainly change rapidly, the PIO team will prudently identify the areas with a sustained impact and utilize resources effectively.

6.5.3 Library and Publication Infrastructure

A key part of the Gemini PIO effort has been supporting the Observatory staff, by facilitating functions such as publication tracking, documentation and archiving, publication production, and general library operations. The Gemini Library will continue as a resource in its traditional capacities for books and publications. The degree of archiving and documentation will increase, adding metadata to include all relevant images, video, illustrations, and historical documents. Many of these resources are currently in short-term archival storage will be reviewed, selected, and metadata tagged to make them useful for future generations of staff and historians. A recent initiative has begun to preserve an independent "institutional memory," since the Gemini Library is a resource for the preservation of information and data of all types. This effort will continue over the next five years. In addition, the long-term archival storage of these items continues to be important.

The library also tracks publications based on Gemini data. The database of refereed papers is integrated into the Gemini Science Archive, where Gemini observing programs and refereed publications can be identified and cross-referenced. The database is being fine-tuned to make it easily available as a powerful tool for bibliometric studies. The database will continue to be updated and monitored by the Gemini Librarian.

6.6 Society as a Whole

Gemini continues to have a significant impact on the local and regional areas surrounding its observing sites. In addition to the effects outlined above, it has been a major source of jobs in these local areas, both of which are economically depressed in many respects. On an ongoing basis, Gemini's current operations and development directly contribute about $40 million annually to the world economy, much of it flowing into observing-site and Partner communities. Since 1989, Gemini has outsourced more than $224M to commercial contractors and educational not-for-profits in the site-host areas and the world, primarily in the Partner countries. This has promoted job development and the growth of technology infrastructure in many locations on a global scale.

Developments in adaptive optics, such as those at Gemini, already have benefited medical imaging technology. The development of technology for high-powered, solid-state sodium-line lasers, under a partnership between Gemini, Keck, the Center for Adaptive Optics, and the US Air Force, is expected to have significant spin-off effects in many other laser-based technologies.

Gemini's research will impact human society as a whole by contributing to finding clearer answers to the fundamental origins questions about the cosmos, life, and humanity's place in the Universe. The scientific issues that Gemini will address, and the knowledge that will flow from those efforts, will contribute to humankind's understanding of the essence of Nature, including our deepest concepts of ourselves.

Four hundred years ago when Galileo first used a telescope to enable him to make detailed drawings and studies of the Moon, he could not have predicted the contribution he was making to the first human journey to the Moon three hundred sixty years later. While the outcomes from Gemini's contributions to the body of astronomical knowledge cannot be predicted in detail, experience teaches that these endeavors will produce real benefits.

7. Management and Budget

7.1 Organization and Administration

The Gemini Observatory organization was restructured during 2011, and several key personnel have changed. Doug Simons concluded his term as Gemini Director in May 2011, and Frederic Chaffee is serving as Interim Director while a search for a permanent replacement is underway, to be in place by mid-2012. The new position of Chief Financial Officer (CFO) has been created, which Diego Correa will assume in January 2012. Another significant change was to consolidate all of operations activities, including engineering and science, into a single division. The number of staff assigned to the Development group has grown, in recognition of the development activity occurring within the Observatory.

Within Operations, there is a Head of Science Operations for each site, and a Head of Engineering Operations for each site, all of whom report to the Associate Director (AD) for Operations. A manager leads the Science Operations Specialist team at each site, reporting to the local Head. One supervisor leads the total Data Process Development team. The Heads of Science Operations serve directly as managers of the astronomy staff at their local site. Within Engineering Operations, there is one manager of each functional group, who may be located at either site and who reports to the local Head of Engineering Operations. A functional lead is identified for the other site.

The Development branch is organized largely according to key projects, each of which is led by a project manager. The Systems Engineering Group and Adaptive Optics are also part of this division. This larger group is now led by a new AD for Development.

7.1.1 Results of Recent Management Changes

Instrumentation and user tools

The management changes described above have produced important positive results during 2011, notably toward fulfilling the Gemini Board's top priority to deliver and operate instruments the user community desires. Now Gemini is poised to offer several capabilities that have been long-desired by observers. With the new AD for Development, changed project management approaches allow more focus on internal and external instrument projects to complete work in progress and to deliver new capabilities for the users. These include several key projects described above: improved red response for GMOS, FLAMINGOS-2 as a facility-class instrument, and GeMS for scientific use, along with improvements to the Phase I and II user software tools.

Budget management

Prior to 2011, Gemini's budget management approach was largely a vestige of the construction era and had become intractable for the era of operations. In May, the senior accountant at Gemini was replaced by an interim CFO provided by the AURA Corporate office. While a worldwide search for a permanent CFO was undertaken on Gemini's behalf by an executive search agency, the 2011 and projected 2012 budgets were completely redone and redesigned to better meet the needs of Observatory management and Gemini's various oversight and governance bodies. With the new Gemini CFO, we expect much more transparency and control for the Gemini budget as we move into the impending time of great budgetary challenge for the Observatory.

7.1.2 Administration

The International Gemini Agreement governs all aspects of the Observatory, enabling the Gemini Observatory to serve the interests of all its member countries. The National Science Foundation acts as the Executive Agent for the Gemini Board under the terms of the International Agreement. NSF administers a Cooperative Agreement, with AURA as the selected Managing Organization. Policy and financial decisions by the Gemini Board are executed by the NSF through this Cooperative Agreement. As the parent organization and legal entity, AURA manages the Gemini Observatory as a distinct operational unit. AURA is accountable to the Gemini Board, through the NSF, for operating the Observatory within specified parameters of performance, schedule, scope, and budget. The NSF provides the necessary authority to enable effective execution. In turn, AURA delegates authority to the Gemini Director and provides oversight in accordance with AURA policy through the AURA Oversight Council for Gemini (AOC-G).

7.2 An Integrated Observatory – A Collaboration of Communities

Acting on behalf of their respective science communities, the Partner agencies are the Observatory's "customers". Hence, Gemini must strive to effectively and efficiently meet the diverse science objectives of all Partner science communities. The international Partners and Gemini have collaborated to develop an integrated working structure that connects the Partner countries' astronomy communities to the Observatory. The Observatory is joined to the Partners at two levels: first through their agencies on the Board, and second through direct links to the Partners' national astronomy communities.

The communities are linked through their respective NGOs and the oversight committees. These actively help to shape the science program and science operations. For example, semi-annual meetings of the Operations Working Group provide an additional effective forum where NGO representatives and Gemini staff review performance, issues, and user feedback, in support of ongoing operations. The STAC provides the strategic perspective for scientific advancement. Overall, the Gemini Board, NSF, AURA, and partner-community groups monitor, coordinate, advise, and otherwise interact with the Observatory to ensure optimum performance. This integrated approach makes the agencies and their science communities close participants in the Observatory's science and instrumentation programs; they are a *working part* of the Observatory itself.

Community, NGOs, and Observatory interactions also take place at the regular Gemini Science Conference and Users' Meeting. The last two forums were held in Brazil in 2007, and (in a joint science conference with the Subaru Observatory) in Kyoto in 2009. We are planning for the next meeting in July 2012, in San Francisco.

7.3 Internal Performance Oversight

In addition to independent oversight by the NSF/Gemini Board and the AURA Board, the Observatory's organizational structure provides internal checks and balances to monitor and improve performance. Sustaining excellence in the Observatory's performance of its mission requires relevant objective data. Various aspects of Gemini science operations lend themselves naturally to quantitative measurements of Observatory and National Office performance.

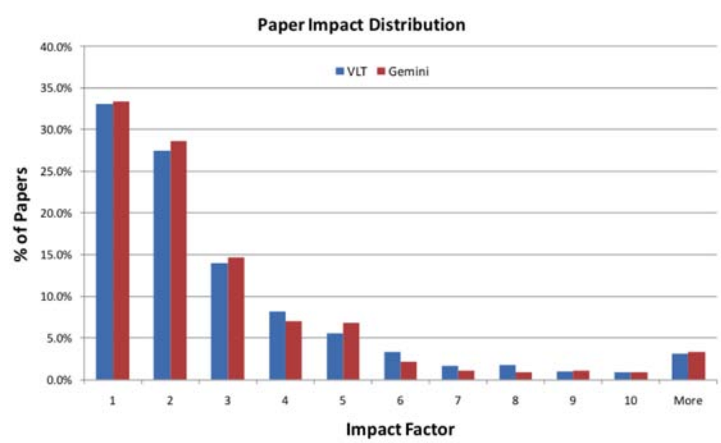


Figure 7-1: The scientific impact of papers published based upon Gemini and VLT data are shown. Noting that VLT started operations several years before Gemini, in recent years the science impact of publications between these two observatories is comparable.

7.3.1 Science Productivity

7.3.1.1 Science Impact Measured by Publications and Citation

The Observatory keeps a very detailed publications database that is updated on a weekly basis. The research productivity based on the number of papers and citations is one of the criteria for assessing the quality and impact of the science delivered by Gemini users. Figure 7-1 compares the scientific impact of Gemini and VLT publications, based on the ratio of citations received by a specific paper to the mean number of citations for all Astronomical Journal papers of the same year. Thus, the vertical value at an Impact Factor of 5 represents the percentage of papers receiving five times as many citations as the average number of citations for all papers. This analysis indicates that the scientific impact of the published research conducted at Gemini has comparable impact to that which is performed at VLT. Using the Gemini publications database, the number of publications is tracked as a function of instrument, original program ranking, observing mode and several other criteria. It provides a robust basis for analysis of indicators of the popularity and productivity of all Gemini capabilities and observing modes. (See Section 4.1 for further discussions of performance metrics.)

7.3.1.2 Quality of Services Provided Through the Distributed Model

The oversubscription rate—the ratio of requested observing time to time available—is tracked for each telescope on a semester-to-semester basis. These values are a measure of demand and can be compared to similar information from other observatories. Figure 7-2 compares Gemini's rates to those of VLT. It should be noted that VLT reserves separate blocks of available time for queue and classical programs. By contrast, Gemini does not allocate a fixed fraction of time to classical programs, and most proposals are for queue time. Nevertheless, for queue observing both Gemini and VLT treat requested time as that of their respective top two queue-ranking bands (i.e., those that are likely to be scheduled), which is plotted here. While the algorithms are not exactly the same, both systems are measuring essentially the same thing, requested observing time to available observing time, and the values and the trends are very similar.

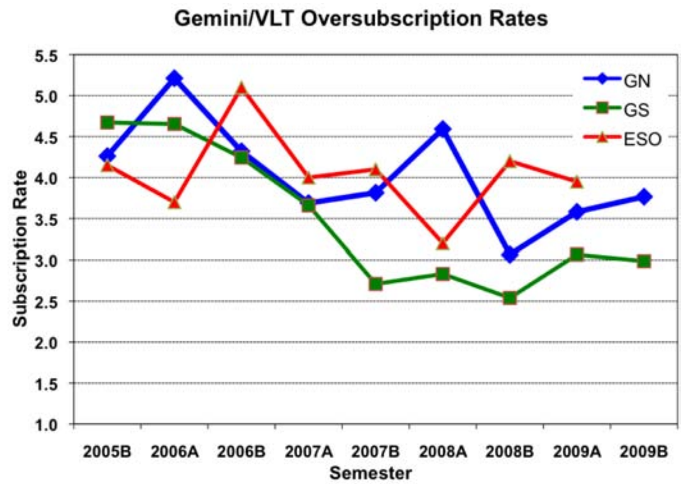


Figure 7-2: A comparison of the oversubscription rates for Gemini North and Gemini South with the average rates of the four VLT telescopes. Both Gemini North and Gemni South generally show comparable values and trend patterns as the VLT. However, the recent lower rates at Gemini South are a consequence of the limited instrument suite offered which will be addressed through the new instrumentation described previously.

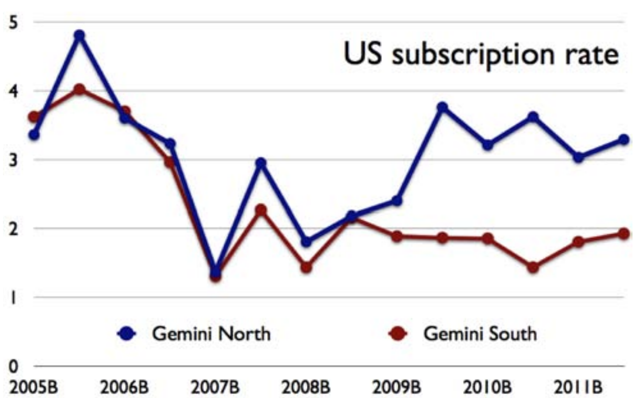


Figure 7-3: Subscription rates for US time on Gemini North and South. The rates in this chart are calculated with respect to *all* time available, not only that available to Bands 1 and 2 (as shown in Figure 7-2).

Compared with Gemini North, Gemini South has historically offered a more limited instrument suite. We expect the rates of the two telescopes to become comparable when FLAMINGOS-2 and GSAOI are available as facility instruments on Gemini South. This difference is also apparent in the recent US oversubscription rates (Figure 7-3). The healthy demand for Gemini North demonstrates that access to astronomical capability is the crucial variable.

Feedback from observers is also a useful tool. The Users' Committee is charged to concentrate on users' needs, and their concerns also reach Gemini informally.

7.3.2 Time Accounting

Each observing program is charged the time spent executing that program. These aggregated charges comprise the overall Partner usage. However, a finer level of measurement is available from the Observatory Control System, since it timestamps each step of the observation. Thus, the time required to slew the telescope, reconfigure it, acquire the target, carry out the observing sequence, perform calibrations, and assess data quality are all recorded. Similarly, time lost due to weather or failure of either a telescope or instrument, or time spent on scheduled engineering activities are also recorded. Time charges are tracked and reported at each Gemini Board and Operations Working Group meeting.

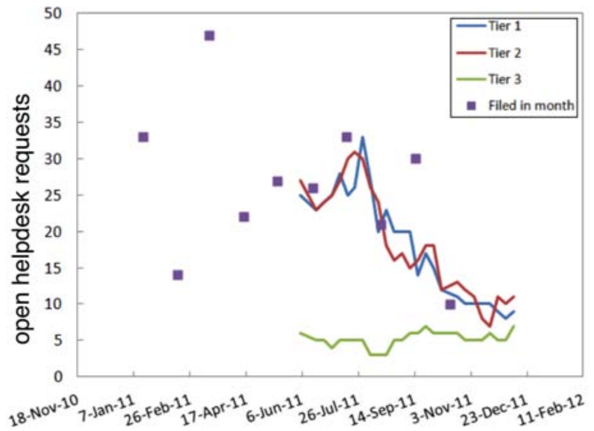


Figure 7-3: The number of open Helpdesk requests has declined, showing improvement in this key performance indicator.

7.3.3 User Helpdesk Support

The distributed support system of the NGOs and Observatory responds to user queries of the Helpdesk. Requests are escalated through the layered system (from Tier 1 to 2 to 3) if more expertise is required. A metric of responsiveness is the number of outstanding open requests, which shows the desired trend of decline recently (Figure 7-3).

7.3.4 Telescope Down-Time

An important metric to minimize is the amount of time lost to faults, due to problems with instruments and telescope systems. The goal is not to exceed 4% time loss, which Gemini South typically achieves (Figure 7-4). The loss rates at Gemini North are currently somewhat higher, though the trend over the last couple of years shows progress in reducing the fault rate. Beyond merely tracking faults, Gemini identifies the sources of greatest time loss, in order to work preferentially to solve these problems. These performance indicators are recorded and addressed weekly.

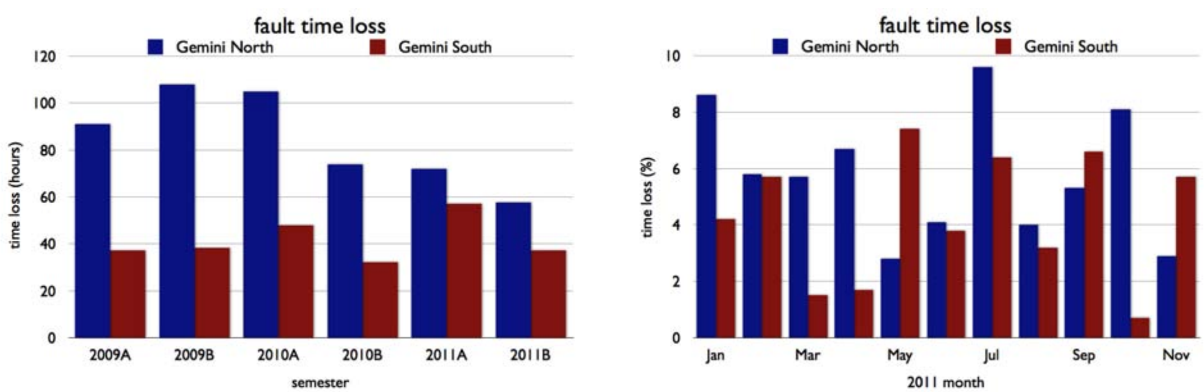


Figure 7-4: Time loss to faults in recent semesters (left) and months (right). Gemini South typically reaches the target of a no more than 4% time loss. The loss rates in the North are currently somewhat higher, but the trend is good, with a significant reduction in time loss since 2009.

7.3.5 Reviews

In close communication with AURA, the NSF, and the Gemini Board, the Observatory participates in periodic reviews of its overall performance that summarize performance metrics, financial data, scientific accomplishments, and other topics relevant to management goals. These include semiannual Gemini

Board meetings, GFC meetings, AOC-G reviews, annual external AURA financial audits, biannual Gemini Visiting Committee reviews, and every-five-year NSF Midterm Term Reviews, which are interspersed with every-five-year extensive NSF Cooperative Agreement renewal reviews. In addition, from time to time, there are non-recurring special purpose reviews at the will of the Gemini Board and NSF.

7.3.6 Gemini Reports

The Gemini Director submits the following Observatory reports through AURA to the NSF to be coordinated with established formal reviews, such as the Gemini Board meetings. While these might reasonably be considered NSF oversight tools, they originate from the Observatory and also provide Gemini with the opportunity to evaluate itself, since the Observatory is reporting on its own performance along a variety of axes. These reports include, but are not limited to:

Annual Progress Report and Program Plan: This covers Observatory accomplishments, the status of scheduled observing during the most recent calendar year, and scheduled projects and issues to be resolved during the following twelve months. The report is finalized soon after the year has concluded and then posted on line[19].

Annual Financial Report: This document summarizes expenditures to date, outstanding financial commitments, and a comparison of costs incurred with budgeted funds.

Master Site Plan: This annual report provides the NSF with a comprehensive update on all buildings and land holdings (owned or leased) controlled by the Observatory. It includes maps, site plans, and textual descriptions of each asset, its purposes and current and expected future needs.

NSF Facilities Project Reports: This actually consists of two annual reports. The first is a pre-year estimate of performance based on objective criteria, such as the number of hours available for scheduled observing programs. The second report is a post-year report on the actual performance based on the defined metric criteria during the performance period.

Partner	Cost Share
US	50.12%
United Kingdom	23.81%
Canada	15.00%
Australia	6.19%
Argentina	2.38%
Brazil	2.50%
Total	100.00%

Table 7-1: Partners' historical shares of operations costs

7.4 Budget

The schedule of contributions for the Gemini Observatory budget is governed by a set of Administrative Guidelines. These Guidelines are agreements made among the members of the Gemini International Partnership, including the NSF; AURA is not a party. These agreements clarify the partnership members, partnership shares, and the timing for the payment of contributions. The historical apportionment of the Gemini shares is shown in Table 7-1.

The fractional shares of the historical program reflected a simple six-member financial partnership. The withdrawal of the United Kingdom at the end of 2012 calls for a revised agreement and a realignment of shares. The Partners have indicated the level of contributions that they will be striving to make in the timeframe to 2015, and observing time shares will be aligned with the financial shares. (See Table 7-2.)

7.4.1 Operations – An Ongoing Commitment

The Gemini Observatory Director annually proposes the following year's budget to the Gemini Board showing the current year and not less than three further years. Through the Gemini Board, the Partners review and approve the current year operations budget and approve, in concept only, the three-year

[19] www.gemini.edu/node/278

Total Contributions	2011	2012	2011-2012 total	% 2 Yr Total	2013	2014	2015	2013-2015 total	% 3 Yr Total
US	19.58	20.07	39.65	53.46%	20.57	21.09	21.61	63.27	67.03%
UK	7.38	7.38	14.77	19.91%	0.00	0.00	0.00	0.00	0.00%
Canada	5.50	5.62	11.13	15.00%	5.62	5.62	5.62	16.87	17.88%
Australia	2.31	2.36	4.68	6.31%	1.79	1.79	1.79	5.36	5.68%
Argentina	1.04	1.06	2.10	2.83%	1.08	1.10	1.12	3.30	3.49%
Brazil	0.91	0.94	1.85	2.50%	1.82	1.86	1.91	5.59	5.92%
Totals by Year	**36.73**	**37.44**	**74.17**	**100.00%**	**30.88**	**31.46**	**32.05**	**94.38**	**100.00%**

Table 7-2: Provisional Partner Contributions, US$M, including operations and development.

planning outlook. As a Designated Member, the NSF representative has veto authority over the budget, as do the representatives of the United Kingdom's STFC and Canada's NRC-CNRC.

The Operations budget is divided into three categories, which are further subdivided. The main components are: Operations and Maintenance, Development, and Support Facility Construction. Table 7-3 identifies these operations funds and their subcategories.

7.4.1.1 Operations and Maintenance

The Operations and Maintenance (O&M) budget supports the day-to-day activities involved in operating the telescopes and facilities. Broadly speaking, these activities are science support, engineering, instrumentation support, administration (including operations costs for base facilities, fleet and mountain infrastructure), information systems, research, public information, safety, and the directorate. The cost details of the Operations and Maintenance plan are based on periodic assessments of top-down and bottom-up staff and non-payroll cost reviews. These reviews are coordinated with the overall operational expectations of the Observatory, and they provide long-term cost projections for the O&M accounts.

7.4.1.2 Development – Investments in Tomorrow's Capabilities

There are two development funds dedicated to the ongoing enhancement of the scientific and technical capabilities of the Observatory. The Instrument Development Fund (IDF) is directed at systems that analyze the light collected by the telescopes, that is, the instruments such as cameras and spectrographs. The Facilities Development Fund (FDF) supports enhancements to the systems that facilitate light collection, like the telescopes and adaptive optics systems.

Expenditure Category	Fund Name	Purpose
Operations and Maintenance	Operations and Maintenance	Operations and Maintenance
Development	Instrument Development	Light Analyzing Instruments
	Facilities Development	Light Collecting Systems and Observatory Systems
Support Facilities	Hilo Base Facility	HBF Construction
	Southern Base Facility	SBF Construction
	Cerro Pachón Dormitory	CP Dorm Construction

Table 7-3: Operations budget funds

Generally speaking, the two development funds are protected from transfers of monies out into other funds, such as O&M, although the Gemini Director, in consultation with the Gemini Board, has discretion in this matter. On the other hand, there is no prohibition against transferring funds *between* the two development funds when the changing needs of the program and prudence so dictate.

The Observatory develops and periodically updates an integrated long-range development plan in collaboration with the STAC and the Gemini community as a whole, as described in Section 5. This resulting plan coordinates the timing and capabilities of the Instrument and Facilities programs with the science requirements and budget realities.

The proposed future development program described in this plan is illustrative of the scope and nature of the program that the Observatory intends to pursue in the coming years. Considerable consultation with the GSC previously and with the STAC has guided the development of the illustrative plan. As emphasized in previous sections, Gemini's international community will be fully engaged in the development of the final plan through their representatives on advisory committees and directly participating in meetings.

7.4.1.3 Base Facilities – Investments in Exercising the Capabilities
The Partnership has supported the construction of the Hilo Base Facility and its two-story expansion building in Hawai'i, the Southern Base Facility in La Serena, Chile, and a small temporary eating facility near the summit of Cerro Pachón in Chile. There are no significant facility construction activities planned in the 2012 – 2015 timeframe.

7.4.2 A Time of Transition
The Gemini Board of Directors directed the Observatory to make innovative changes in operations that would position the Observatory to support its basic operations and maintenance in 2015 at about \$27.75M. This represents an extremely lean budget, approximately a 24% reduction due mainly to the departure of the United Kingdom. Achieving a reduction in operating costs of this magnitude requires the identification and implementation of significant changes, as described in this plan.

Making the transition to the proposed new operations incurs costs. Most notable among these are the preparations for observing from the base facilities rather than the summits (including improving acquisition and guiding reliability), upgraded observing software, and the costs associated with the effects of downsizing. Direct costs associated with downsizing staff include: change management consultation and focused retention programs to decrease talent flight and address morale in the transition period; severance costs assured by personnel policy; and out-placement costs, where required. The transition costs will be funded, to a great degree, with both committed and uncommitted carry-out funds from 2010.

7.4.3 Five-Year Budget Explanation
In the sections that follow, the program costs for 2011–2015 are presented and discussed, first from the perspective of the overall program and then in terms of the NSF contributions.

7.4.3.1 Overall Scope
The Observatory staffing plan shows the people required to provide queue and classical observing support, the operations and maintenance of two 8 m class telescopes with sophisticated laser adaptive optics systems, data reduction capability that provides sufficiently processed data to the user and the Gemini Science Archive, a public information and outreach program, a safety team, an instrument development coordination team, and an administrative, facilities and infrastructure team that supports all observatory activities. The staffing plan that meets the budget indicates a steady decline from 2010 levels of 198.63 work years to a planned steady-state level of 167.00 work years in 2015. This is a reduction of 31.63 full-time equivalents, about 15.9% of the work force.

Not surprisingly, nearly three-fourths of the total labor effort is dedicated to science support that assists users with observing and related activities; information systems that provide connectivity and link operations at and between the observatories; and engineering, which supports the existing systems and develops new capabilities.

7.4.3.2 A Five-Year Plan

Budgeting to maintain the planned scope of operations over a five-year period requires analysis of the potential external factors that can significantly affect operations costs. Chief among the external factors that can affect these costs are inflation rates in the US and Chile, exchange-rate considerations (particularly the US dollar-Chilean peso exchange rate), fuel costs (chiefly as they relate to electricity costs, but also for vehicle operations and shipping), and the cost of labor.

The Observatory has chosen to formulate the budget using "normal" values for the external factors that historically have had the greatest effect on expenditures. If, however, economic circumstances in the new funding period have combined effects to significantly increase costs, the Observatory would respond by implementing an existing contingency response plan. The types of actions and approaches that might be taken if faced with extreme and adverse economic conditions, not necessarily in the order they would be implemented include:

- Wage and salary freezes
- Delay of non-critical staff training
- Delay of non-critical maintenance
- Delay of non-critical development projects
- Acceleration of planned staff reductions

7.4.3.3 Overall Observatory Costs – Shared by All the Partners

The overall costs of the Gemini operations program is borne by the Gemini Partners according to the cost-sharing agreement outlined in Table 7-1 through 2012 and, provisionally, in Table 7-2 post-2012. Table 7-4 shows these costs on an annual basis, according to the budget fund areas described in Table 7-3.

The budget for the five-year period includes expenditures for completion of instruments started prior to 2011 (e.g.. FLAMINGOS-2 and GPI), GeMS completion, and transition projects such as the new A&G systems, base facility observing and science operations software. These additional expenditures rely on prior-year contributions. The Instrument Development Fund (IDF) expenditures for 2011 are notably higher than the subsequent years, reflecting the scheduled completion of instruments already in the pipeline. The Facilities Development Fund (FDF) expenditures include completion costs for GeMS and the start of the new A&G systems in 2012, and the continuation and completion of the A&G expenditures through 2014. The O&M budget includes funding for transition projects (base facility observing and science operations software) in all five years and, nonetheless, shows a steady decline as operating changes are implemented. Transition costs of about $121K are included in O&M in 2015. When these are subtracted from the budget, the resulting basic O&M budget in 2015 is $27.76M, thus matching the guidance given to the Observatory by the Gemini Board.

Fund	2011	2012	2013	2014	2015	Total
Operations & Maintenance	30,398,509	30,255,524	29,475,583	28,137,431	27,889,344	146,156,391
Facilities Development	1,155,092	1,019,500	2,039,000	1,021,439	-	5,235,031
Instrument Development	9,506,922	5,871,153	4,878,668	4,944,740	5,035,050	30,236,533
Southern Base Facility	41,511	-	-	-	-	41,511
Total Budget	41,102,033	37,146,177	36,393,251	34,103,610	32,924,394	181,669,466

Table 7-4: Overall Gemini operations spending by fund (US$)

About 80% of the operations budget is dedicated to sustaining the day-to-day operation of the Observatory and its services. The remaining 20% of the budget is dedicated to the continuing development of new instrumentation and facilities capability.

Cost Category	2011	2012	2013	2014	2015	Total
Labor	18,175,580	18,517,563	18,010,370	17,648,025	18,013,371	90,364,909
Supplies & Materials	3,112,567	2,911,502	2,794,794	2,449,688	2,409,827	13,678,378
Travel	1,309,450	1,318,586	1,241,166	1,271,198	1,075,783	6,216,183
Purchased Services	4,815,791	4,919,662	4,985,967	4,897,820	4,624,562	24,243,802
Subcontracts	11,903,161	7,942,881	7,843,841	6,462,752	5,457,314	39,609,949
Equipment	870,326	678,356	673,887	574,696	566,661	3,363,926
AURA Management Fee-Fixed	150,000	150,000	150,000	150,000	150,000	750,000
AURA Management Fee-F&A	765,158	707,627	693,225	649,431	626,877	3,442,318
Total Budget	41,102,033	37,146,177	36,393,251	34,103,610	32,924,394	181,669,466

Table 7-5: Overall Gemini operations spending by cost category (US$)

Table 7-5 provides the overall Gemini operations costs by natural categories. The single largest cost factor is labor, comprising 50% of total costs. Subcontracts comprise about 22% of total expenditures, including most development costs. Purchased Services, including such things as mountain infrastructure and facilities costs, is the third largest cost factor, comprising about 13% of the total program cost.

The AURA recovery of costs for Corporate Office operations consists of two elements: (1) overhead (Facilities and Administrative [F&A] Costs) costs expended as an annually negotiated rate with the NSF, and (2) a fixed management fee for the duration of the program. The values shown here include the current approved rate applied to expected observatory costs and should be considered as a placeholder subject to the annual negotiation.

7.4.3.4 NSF Cost Share – The US Contribution

Table 7-6 shows the NSF contributions required to support the program as set out for Gemini operations over future years. Because of the nature of the international agreement, Gemini will not apply for supplementary funding for instrumentation, infrastructure investment, etc. Thus, these values represent the expected total US contribution to Gemini to support all its activities over this timeframe.

Fund	2012	2013	2014	2015	Total
Operations & Maintenance	16,189,764	16,043,835	16,966,606	18,022,087	59,127,410
Facilities Development	545,536	1,109,847	615,918	-	1,998,533
Instrument Development	3,333,942	3,417,289	3,502,722	3,590,290	12,177,272
Southern Base Facility	-	-	-	-	-
Total Budget	20,069,242	20,570,971	21,085,246	21,612,377	73,303,215

Table 7-6: NSF contributions to Gemini operations spending by fund (US$)

8. Summary of the Five-Year Program

The Gemini telescopes were built and commissioned during the 1990s and started science operations in late 2000 (Gemini North) and 2001 (Gemini South). Since then they have been in essentially continuous operation, and with ongoing instrument development, they will continue to be leading research facilities and science machines into the future. The technologies used in fully active telescopes like Gemini are a triumph of modern engineering and demonstrate that the large gains made by the current 8-10 m class telescopes are not solely attributable to aperture but to successful active and adaptive optics systems as well. Unfathomable when the 4 m generation of telescopes dominated ground-based astronomy two decades ago, the current generation of large telescopes has demonstrated that the turbulent structure of the atmosphere is amenable to analysis and correction. Also, new developments in instrument design (multi-object, integral field unit, immersed gratings, cryogenic systems, large format detector technology, etc.) for all wavelengths have equipped astronomers with enhanced tools that would have been dreams a few decades ago. Because progress in astronomical research is inextricably linked to the technologies used in observatories, Gemini is and will continue to be a leader in bringing these forefront technologies to its international community.

The plan for future Gemini operations builds on the past investments in the Observatory. Beyond the telescopes and instrument suite, we aim to take advantage of and cultivate the developments in operations and technical expertise, despite budget challenges. The core aims of the Observatory can be maintained, although doing so requires continuing investment. Delivering productive instruments for the Gemini community, for example, demands current staff effort beyond basic operations in the short term, and long-term contributions for new capabilities. An effective queue operation can build on experience to use the available telescope time well, but as this plan illustrates, its successful execution in the future must proceed differently, with reduced human effort. The development of remote operations capabilities offers a challenge as Gemini changes, but it is an opportunity for true transformation with the prospect of much greater direct interaction between the community and Observatory through these changes. While preserving the essential attributes of the Observatory remains paramount in this plan, budget driven losses are significant with the bulk of the necessary cost savings are derived from staff size reductions. In turn this means the margin available to respond to unexpected or unplanned problems will be reduced, with some risk to on-sky performance. However, the fundamental end-state of Gemini under this plan provides a long-term balance between funding resources and operational needs, and it is ultimately sustainable.

Consistent with the working culture at Gemini, this plan to operate Gemini in the 2012-2015 timeframe is future-focused but grounded in lessons learned from the past. It reflects Gemini's continual commitment to improve, to be responsive to community needs, to lead on strategic fronts, to operate efficiently in a cost constrained environment, to build upon investments made to date, and to yield a world class scientific product that all Gemini stakeholders can be proud of. Examples of proposed new activity that reflects these top-level objectives include:

- **Instrumentation** – Release for community access the Gemini Planet Imager and develop new "workhorse" instruments intended to provide fundamental capabilities of interest to the community and replace aging instruments. During this period and for the first time in the life of the observatory, both Gemini telescopes will be outfitted with exceptional near infrared imagers and spectrometers, and it is anticipated that demand for Gemini observing time will rise accordingly.

- **Adaptive Optics –** Release for community access GeMS, yielding advanced laser AO systems at both Gemini sites. Gemini AO systems will feed near-infrared instruments capable of single-slit, multi-slit, or integral field spectroscopy, as well as broad band and narrow band imaging.

- **Science Operations** – Using experience gathered to date, both classical and queue-based modes will continue to be supported. Queue operations will be streamlined using non-research observers, and both sites will migrate to base facility operations. We will also develop innovative modes to allow real-time remote participation of PIs in the gathering of data for their programs.

- **Data Management** – Building upon investments made to date in the GSA and PyRAF development efforts, more extensive data reduction algorithms and recipes will be released to the community. In parallel, a pipeline data-reduction system will be completed to support in-situ quality assurance of data to further increase summit operations efficiency.

- **Engineering** – Continue to develop the innovative observatory wide planning system, which closely couples resource allocation across a myriad of projects with both near-term priorities and long-term goals. With further anticipated enhancements, Gemini's planning system is expected to become a model for the benefit of other major research facilities. Engineering will also be central to developing base facility science operations and the successful commissioning of several new instruments.

- **Administration** – Continue to update the communications systems, which sustain the day-to-day operations of Gemini's highly distributed workforce. In addition, Gemini is taking the initiative in the "greening" of the Observatory in the new decade, reducing the energy costs and the carbon footprint as part of a broader strategy to further enhance Gemini's scientific product in a cost constrained setting.

- **Safety** – Instill a modern safety culture at Gemini, the cornerstone of which is the recognition that safety is everyone's responsibility. Like Gemini's planning system, the safety system has already produced exceptional results and holds the promise of benefitting other facilities operating in remote locations.

- **Outreach** – The future astronomers, engineers, and administrators that will operate and use Gemini in the decades to come are in our midst—they are the children that Gemini's outreach program is designed to excite by the possibility of discovery in the skies above. Developing scientific literacy across the population is valuable. During the 2012-2015 timeframe literally tens of thousands of children will encounter Gemini's outreach program in Hilo and La Serena. If only 1% is drawn into scientific or technical careers by such contact with Gemini, our outreach program will have made a meaningful contribution to the much broader effort across the partnership to nurture tomorrow's leaders in science.

- **Broader Impact** – Though Gemini's staff is already diverse, improvements will be sought, particularly in the area of recruiting women engineers, and black engineers and astronomers. In addition, we will develop new and enhanced mentoring programs. Among other objectives, these will help train mentors on the staff so they can offer important career guidance, particularly to our younger postdoctoral staff. Gemini has continued to make major additions to the astronomy research infrastructure, including major improvements in telescope design and optical systems, breakthroughs in high durability, high reflectance mirror coatings, great strides in NIR LGS adaptive optics and world-class MIR, NIR, and optical instrumentation. These positive effects will continue well into the future.

These goals, consistent with the direction of the Gemini Board and the needs of the stakeholders, are feasible within the predicted budget envelope. The strategic goals outlined above and described throughout this plan represent a mature facility that has taken its rightful place alongside other 8-10 m class observatories as one of the great portals to the Universe available to today's society.

9. Strategic Vision to 2025

9.1 Overview

A number of important trends have emerged in recent decades with the globalization of economies, societies, and scientific research. These include the emergence of large science teams to conduct cutting-edge research, the assemblage of major research facilities through international collaboration, and the unprecedented scales (in terms of cost and complexity) of research being conducted by these large teams at these large facilities. This trend will doubtless continue well into the next century, as the information exchange infrastructure needed to sustain it grows rapidly and the need to make meaningful progress in basic research drives collaboration and defies the borders of the past. No single country will have the means to build the mega-facilities for research in the future. In that sense, Gemini Observatory has been a spearhead in forging, within the astronomical community, the types of international working relationships that will help foster the research of tomorrow.

It is in this vision – *that the future of astronomy relies critically upon international collaboration* – that we ground today's strategic plans at Gemini Observatory. A core objective of this vision is to enable research opportunities that would otherwise be impossible, for sociological, technical or financial reasons. A combination of strategic coordination of developing new capabilities at various facilities and time-exchange programs designed to open access to facilities that have historically been inaccessible, are the building blocks for our vision. Below we provide context and examples of how this is being conducted today, and explain how this will lay a foundation for much more extensive applications of these same principles in the future.

9.2 Mauna Kea in 2012 – Today's Centerpiece for International Ground Based Astronomy

With sites in Hawai'i and Chile, a highly international heritage, and world-class capabilities, Gemini is uniquely poised to take a leadership role in nurturing inter-observatory collaborations that could transform the way ground based astronomy is conducted in the future. In the context of developing collaborations with other facilities, Gemini-North is key, though Gemini-South clearly has an important role as well given its proximity to LSST. The collective scientific product and impact of the Mauna Kea observatories is second to none on a global scale, as they comprise the largest collection of astronomical light gathering power on earth. The Mauna Kea observatories were built and are operated by astronomers, engineers, and administrators from all over the world and already function as an international

Figure 9-1: The summit of Mauna Kea is shown, with the peak of Haleakala on Maui in the background. Together these facilities on Mauna Kea represent the largest collection of ground-based astronomical observatories in the world.

collaboration at many levels. They represent a natural conduit for international research and high-tech development activity in the entire Pacific region, with Hawai‘i at the crossroads of the future.

Currently there are 13 telescopes operating on Mauna Kea that collectively make observations of the Universe from radio to ultraviolet wavelengths of light (Figure 9-1). The fact that over a billion dollars has been invested in building and operating the Mauna Kea observatories to date is a testament to the superb properties of this site and the opportunities it represents. The exceptionally dry conditions at this high altitude site are particularly well-suited for sub-millimeter and infrared observations. Each night, observations ranging from ultra-high resolution interferometry of compact astronomical objects to wide-field panoramic imaging of the sky might be performed. In many cases objects first discovered at one Mauna Kea telescope are then subsequently examined in greater detail or with different instrumentation at another telescope, consistent with the spirit of collaboration that makes optimal use of these remarkable facilities (Figure 9-2).

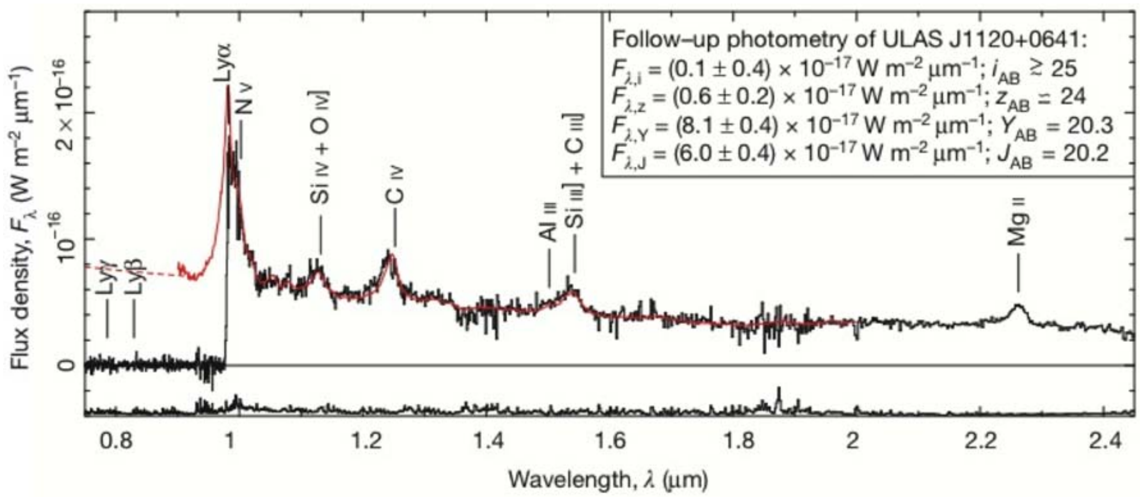
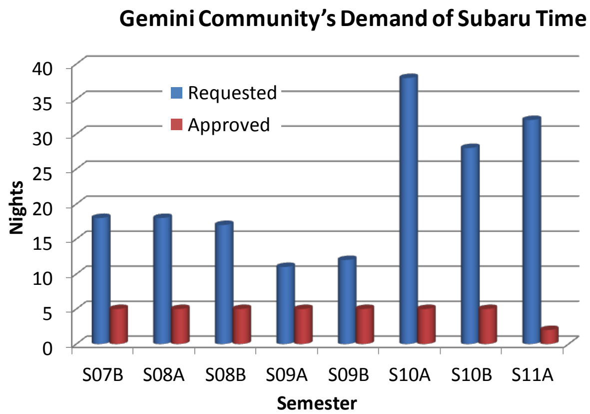


Figure 9-2: The z = 7.1 quasar spectrum (black) offers an example of the power of the Mauna Kea telescopes used collectively. These NIR observations with GNIRS on Gemini North (longward of 1.005μm) were made in the same semester the candidate was discovered in the United Kingdom Infrared Telescope Infrared Deep Sky Survey (UKIDSS) eighth data release. (Credit: Mortlock et al. 2011 Nature 474 616)

9.3 Recent Examples of Inter-Observatory Collaboration

Using this foundation, a number of important initiatives have been launched in recent years that serve as pathfinders for more extensive forms of collaboration in the future. First is the time exchange programs with Keck and Subaru. Already nearly a decade old, this informal program provides access to these large format telescopes across distinct communities. The time exchange program has been an excellent success and is poised to expand considerably in the future. Figure 9-3 shows the demand from Gemini’s community for access to Subaru, and the inverse. The oversubscription levels from both sides have been healthy, sometimes approaching 5 or 6 times.

Previously, the number of exchanged nights had been capped at 5 per semester, hence the uniformity in the number of nights approved in this figure. This cap was put in place to ensure minimal disruption to baseline operations while the mechanics of the time exchange program were ironed out. The experience has been successful, and the most recent semester (2012A) offers 8 exchanged nights. Ongoing negotiations between Gemini and Subaru, which will be codified in a Memorandum of Understanding between these observatories, should expand this number and also enable the exchange of queue time at Gemini for classical time at Subaru (at an agreed exchange rate). Already, both observatories place no restrictions on which instruments are offered through the exchange program. Of course to make this



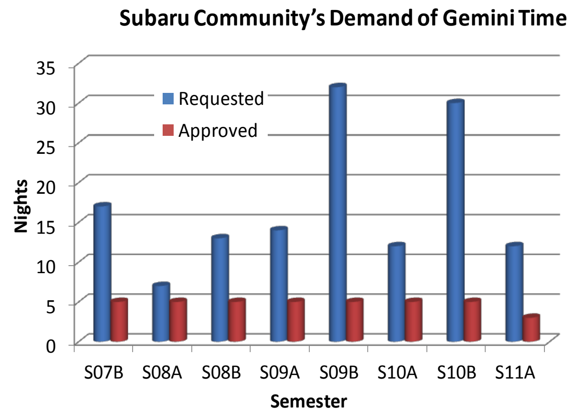


Figure 9-3: Several years of time allocation through the Gemini/Subaru exchange program is plotted above. The ratio of requested to approved nights indicates a healthy demand (in some cases 5–6 times oversubscription). An artificial cap of 5 nights per semester has limited the amount of time exchanged through this program through 2011A.

work, observatories participating in the exchange program must offer something that has "market value" to the community requesting exchange time. Historically, Subaru astronomers have shown the most interest in Gemini-North IFU systems and Gemini-South MIR applications—capabilities they do not have at Subaru. Likewise, the Gemini community has gained access to SuprimeCam through this program—a wide field optical imaging capability that Gemini does not (and cannot) offer. No exchange of cash is involved and each observatory uses its existing Phase I proposal system to support proposals. As a result the management overhead associated with this exchange program is fairly small and bureaucratic complexities associated with trying to formally merge existing facilities are bypassed, while gaining considerable scientific benefit by expanding research options for previously disparate communities.

Beyond time exchange, pathfinders in inter-observatory development programs also exist across the Mauna Kea observatories. These are crucial to avoid duplication of instrumentation and to coordinate long-range development plans to optimally support time exchange programs. In fact time exchange programs and coordinating new instrumentation development must go hand-in-hand to preserve the long-term viability of the overall system. Perhaps the most extensive effort to date in coordinated development was in the form of the Wide-field Fiber Multi-Object Spectrometer (WFMOS) joint development program, again involving Gemini and Subaru. This project dovetailed with Subaru's HyperSuprime Camera (HSC) project – a ~\$50M 1.5° imager employing fully depleted CCDs with extreme red sensitivity that will see first light in early 2012. The WFMOS designs Gemini was pursuing would opto-mechanically interface to the prime focus corrector needed for HSC. Combined with other prime focus infrastructure, the project was designed to split costs on a major new multi-object spectrometer with unprecedented multiplexing capabilities. In addition to developing the technical studies for WFMOS, an extensive draft inter-observatory agreement was negotiated between Gemini and the National Astronomical Observatory of Japan, which included terms for joint surveys using this remarkable system in the future. Unfortunately the cost for WFMOS proved to be too large for the Gemini Partnership, so the project was terminated after the design study phase. Had it gone forward though, it would have driven the time exchange program between Gemini and Subaru in bold new directions, yielding a "system" of three 8 m telescopes equipped with unmatched wide field optical imaging and spectroscopy, as well as infrared and laser AO capabilities including MCAO at Gemini-S. Combined, the Subaru/Gemini inter-observatory collaboration would have been a formidable competitor to VLT. Though it did not go forward, the WFMOS initiative demonstrated the potential of merging strategic plans, coordinating the development of new instrumentation, and forging agreements to share telescope time in a seamless manner, all without the exchange of cash or merging independent observatories, as a sound approach to leveraging the remarkable capabilities of these facilities.

9.4 Future Opportunities

Though on a smaller scale, an inter-observatory collaboration between Gemini and CFHT serves as a good example of innovative resource sharing. The GRACES project, which is underway now, is designed to fiber feed the CFHT high resolution optical spectrometer ESPaDOnS from Gemini-North. A deployable fiber feed module will be built into GMOS-N, feeding a ~300 m run of high performance optical fiber that will be coupled to the ESPaDOnS entrance image slicer (Figure 9-4). The first implementation of this hybrid telescope/instrument system will be used to demonstrate the anticipated performance of the system (which is expected to exceed Keck's HIRES at red wavelengths) before it is further developed into a full facility class system. Gemini is funding this new capability, with the cost for GRACES an order of magnitude below what it would cost to develop a comparable system independently, from scratch at Gemini. Furthermore, since CFHT spends the bulk of its time using instruments to perform panoramic observations, access to ESPaDOnS by the Gemini community should meet demand.

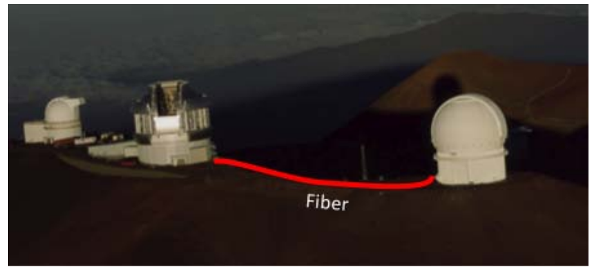


Figure 9-4: A first in astronomy, two major independent observatories on Mauna Kea will be joined by a fiber, feeding a high resolution optical spectrometer at CFHT with photons collected at Gemini-N.

This program may extend into the deployment of SPIRou at CFHT, which is a fiber fed 1-2.5 micron high-resolution spectrometer scheduled to be deployed at CFHT around 2015. SPIRou would provide high-accuracy radial velocity spectroscopic measurements, especially in search of Earth-like planets around low- and very-low-mass stars, which cannot be probed at visible wavelengths. The high resolution (R~75,000) would also be broadly applicable toward studies of magnetic fields on stars and their role in planet formation, and Galactic archaeology. Again, *this type of innovative collaboration yields millions in cost savings for new instrumentation, while opening up new avenues of research for the broader international community on Mauna Kea, including Gemini's community*.

Another area in which the Mauna Kea observatories have excelled is in laser adaptive optics, and future cooperative developments can broadly serve the scientific stakeholders. With 4 laser AO systems in operation today, no other collection of telescopes in the world approaches the depth and breadth of adaptive optics capability now in Hawai‘i. Next-generation AO systems currently under consideration include a high order laser tomographic system at Keck that can operate at visible wavelengths, Ground Layer AO systems at Gemini-North and Subaru, and an extreme wide field (1 deg) NGS Ground Layer AO system at CFHT. These systems are all in the formative stages of development and the ground for collaborative development remains fertile, though significant additional funding will be required to make this next revolution in adaptive optics possible.

An approach that may enable these new AO systems, with considerable benefit to the broader community, would be the use of "mid-scale" funding from the NSF. Under this approach, the University of Hawai‘i would act as the hub for developing these systems, providing lab, shop, and administrative infrastructure in their existing building on the University of Hawai‘i-Hilo campus. Participating Mauna Kea observatories would merge technical expertise to generate a number of advanced AO systems at each facility. In exchange for financial support, participating observatories would agree to provide telescope time to the US community in a program akin to the TSIP program except specifically target AO development, consistent with the 2008 US community AO Roadmap[20]. This win-win strategy would capitalize the exceptional AO talent and singular investments in Hawai‘i now, while yielding exciting new capabilities and enabling access to a myriad of others for the US community. It is fair to say that no

[20] http://www.aura-astronomy.org/news/AO_Roadmap2008_Final.pdf

other site is better positioned today to leverage past investments and unique expertise than the Mauna Kea observatories are in adaptive optics and this approach could open access to a large range of instruments on Mauna Kea to the US community at an unprecedented level.

On the time scale of the next 10-15 years, possibilities for collaborative development on Mauna Kea exist at many scales, ranging from projects that cost ~$1M (GRACES) to tens of millions (mid-scale AO program) to hundreds of millions of dollars. Though still in an early stage, momentum is building toward the establishment of a major new capability that might involve inter-observatory cooperation on a scale that rivals what was attempted with WFMOS. More specifically, in the aftermath of WFMOS, the highest ranked new instrument within the Japanese community for Subaru is PFS (Prime Focus Spectrograph), which is similar to WFMOS and in fact relies upon many of the same core technologies and expertise within the community that came together in the WFMOS program. The combination of HSC and PFS would leave Subaru as the premier wide field optical 8 m telescope in the world. It also represents a major scheduling challenge, with both instruments demanding the prime focus of a telescope that will also need to fulfill a number of other strategic objectives for the Japanese community. In parallel, a replacement for CFHT (called Next-Generation CFHT, or ngCFHT; Figure 9-5) is under investigation that would feature a 10 m segmented telescope that would replace CFHT and feed a highly multiplexed wide field MOS. An obvious avenue for exploring collaborative development across these two projects is for Japan to join the ngCFHT consortium, providing PFS as a major in-kind contribution to the project in exchange for much greater telescope time than would be possible on Subaru alone. While still in a formative stage, this example of collaborative strategic planning would produce new capabilities that, given costs and other constraints, may not be otherwise possible. Gemini, with an international composition and facilities spanning both sides of the equator, demonstrated leadership role in jointly developing new capabilities and a time exchange program, and considerable assets to bring to a "market" of collaboration, should proactively engage these exciting opportunities in the future. More importantly, all of this points toward a future for astronomy in the western hemisphere that revolves around an emerging Pacific alliance of communities and agencies in the 21st century.

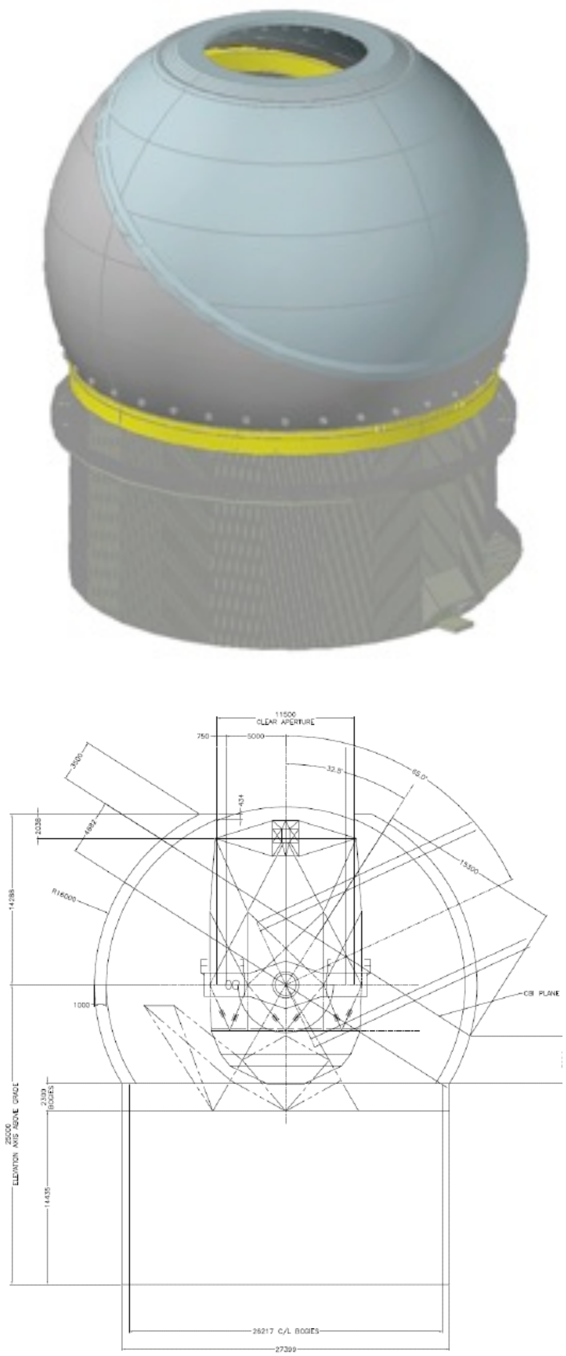


Figure 9-5: The ngCFHT concept is shown above. The load capacity and space envelope defined by the current CFHT pier and dome would allow a 10 m segmented telescope feeding a WFMOS-like spectrometer, enabling a unique wide field spectroscopy capability.

9.5 Gemini in 2025 - The Pacific Observatory Network

International collaboration, along the lines of the examples given above, is the key to developing and operating the astronomical facilities of the future. In a sense this collaborative activity on Mauna Kea is a natural consequence of proximity, common needs, and an innate convergence on a common future (Figure 9-6). While it will be difficult (and undesirable) to formally merge all of these independent observatories into a single amalgam, these initial steps all point toward closer ties that, if nurtured, could lead to an unrivaled network of facilities which we dub for the purposes of this report the Pacific Observatory Network, or PON. Under this concept, this confederation of observatories would agree through time exchange programs to provide access to their sites to all other PON participating communities, and to coordinate the development of new capabilities, as part of a common strategic vision. No exchange of funds is involved and "exchange rates" between classical and queue time are negotiated in advance. While this will yield cost savings, its most significant impact will be the streamlining of research and availability of new opportunities for various communities.

The most important element of the collaboration is the exchange of facilities, to offer astronomers access to the particular and specialized tools they need to pursue their research. Projects under development, such as the extreme AO planet finder on Subaru, capable of detecting planets within 1 λ/D of host stars (O. Guyon 2011, private communication), and the Thirty Meter Telescope, with an advanced AO system, which is necessary to take best advantage of the aperture, would be part of the network. Beyond the new capabilities, the collaborative planning over the coming decade would ensure that the types of instruments developed and operated minimize duplication while still guaranteeing that a robust set of multi-wavelength imagers and spectrometers are available to the diverse international community PON serves.

Figure 9-6: With facilities in the two premier sites for ground-based astronomy in the world, Gemini is uniquely poised to nurture further inter-observatory collaborative development around the Pacific. The prime area for developing new relationships is in Eastern Asia, where strong ties to Japan already exist.

Gemini would continue to offer a crucial connection to the Southern hemisphere, with unique capabilities like MCAO, supported by new (likely spectroscopic) instruments at this time. The members of the collaboration will maintain interests in facilities like ALMA, which will require supporting observations at optical and IR wavelengths. The link to Cerro Pachón would also include LSST, which can provide a steady stream of interesting ToO's to follow in the network queue, whether on either Gemini telescope, Keck, Subaru, or TMT for follow-up observations. The combination of the survey facilities like LSST and ngCFHT along with a collection of unique capabilities for follow-up makes PON an unprecedented discovery machine that would simply be impossible to duplicate any other way. Never has such a powerful array of astronomical tools been unleashed to support research in such a well coordinated manner, with objects being discovered, followed-up, and passed from one facility to another in a seamless manner, across the Pacific.

Gemini also provides the example and foundation for the infrastructure of PON's data access, with all facilities to use a common archive and Pacific wide fiber network. Astronomers would have the option of remotely participating in their queued observations, if they are available on short notice and have a compatible video system. Alternatively, they could monitor progress in the execution of their programs through the PON website and await notification of when their program has been completed to retrieve their data. The data distribution system populates the archive, which becomes an essential node of an international virtual observatory. The data formats and metadata information would be consistent with a searchable database, and the network standards assure that complete calibration data are available for researchers who do not want to use reduced data products. Each observatory within PON would also provide a suite of data reduction software for observations made at their facility. Within the context of either the virtual observatory or the PON collaboration, significant opportunities for cloud computing become real. The current GSA hosts, CADC, already offer high-speed network access to scalable computational resources. The system is flexible, open to custom software that can take advantage of the cluster processing.

9.5.1 Today's Collaborations as the Building Blocks of Tomorrow's PON

PON is built upon a foundation of facilities, investments, and concepts that began decades earlier. The high speed fiber network it would use as its communications backbone was developed by commercial companies and the University of Hawai'i. It was funded, in part, by the NSF in order to link Gemini-North and Gemini-South. The techniques used in the queue based observations were perfected at Gemini, and the remote observing techniques PON offers its community were first developed to operate Keck from around the Pacific basin and the US mainland. The Mauna Kea Weather Center, which began in the late 1990s, would serve as the hub for high-resolution forecasts to be used by all PON observers worldwide. Cross-observatory instrument development and strategic planning, which is needed to ensure a balanced and affordable suite of instruments across all PON facilities, was originated in projects like WFMOS and GRACES. Finally, the inter-observatory time exchange concept, which is central to PON and allows nights to be swapped between facilities like airlines code-share flights, was first developed on a much smaller scale in the ~2000-2010 timeframe. The PON concept is far from fiction. The building blocks needed for PON are substantially in place now and with further leadership and nurturing can become a reality by 2025.

9.6 Process and Constraints

Gemini's process for adapting to the future is already in place. The multiple stakeholders have a voice, through the Board, the STAC, their NGOs, and in direct consultation with the Observatory. These groups are now establishing a framework of goals and priorities for the capabilities Gemini will deliver to users, yet within that structure, priorities and needs can be reassessed and revised, in light of changing circumstances or scientific environment. While the interested community is large and dispersed, the leadership—of the Observatory, the Board, and the STAC, especially—can effectively respond to new opportunities. GRACES is a recent example of such success on a small scale, where an "instrument of opportunity" presented itself and rapidly became part of the active program.

The specific capabilities that Gemini and the PON collaboration pursue will likely be in the context of a world that includes the James Webb Space Telescope (JWST) and Extremely Large Telescopes (ELTs). The capabilities of these new facilities will surpass existing 8–10m telescopes many areas. Nonetheless, Gemini will still have an important role. First, these new facilities will not do everything, and Gemini's offerings can still be distinct in some ways. For example, while more sensitive than ground-based telescopes, JWST will not have high spectral resolution functionality. The operational plans are not well-defined, but it is possible or even likely that truly rapid ToO response (within hours) will not be possible. The second role for Gemini will be to provide complementary observations in support of programs led on JWST or the ELTs. These could be to select targets (e.g., from a broader survey, which none of the specialized telescopes will undertake) or at multiple wavelengths (e.g., to provide optical data that JWST cannot obtain, or less sensitive measurements in some bandpasses, where an ELT is not essential). Finally, in the most obvious way, access to these new observatories will be limited, and astronomers will not abandon their scientific pursuits using "excellent" options merely because "better" also exists. The particular plans for Gemini in this environment will evolve, especially as the timescales for their completion and mission lifetime are refined.

Along the path toward these new facilities, Gemini offers important execution of technical developments. In particular, to realize their full potential, the ELTs will require multi-guide-star AO, for which GeMS is a pathfinder. Moreover, Gemini's operational modes will serve as models. With little time available relative to the level of interest, and with many programs requiring the stringent conditions of AO, observations are likely to proceed largely in queue mode. With individual PIs getting limited allocations, full-service observatory support of a broad community will be required.

Extending Gemini's near-term budget expectation as a model through 2025 means that most of the potential developments discussed above are feasible. Even the most ambitious possibility, GLAO for Mauna Kea, would account for about one-third of the total budget over a 15-year period, thus still leaving support for additional new instruments.

If these assumptions cannot be realized, consideration of prioritization and possible scaling back of future plans necessarily concentrates on facility and instrument development. The cut to the Gemini operations and maintenance budget by more than 20% with the withdrawal of the UK from the Gemini Partnership at the end of 2012 will already be accommodated with transformative, more efficient approaches to science operations and user support. This leaves little room for further trimming of operations and maintenance. With careful management, Gemini can retain its role as the dominant provider of 8-m class time for US astronomers, and the top priority will be developing the instrumentation that researchers need to pursue forefront scientific goals.

Nearly 20 years ago, AURA—with the NSF—was instrumental in assembling an international group of astronomers and technologists who believed that they could build a unique, powerful, ground-based observatory with two telescopes, one in the Northern Hemisphere and the other located in the Southern Hemisphere. Each telescope's clarity of vision would rival that of the Hubble Space Telescope, with a vast single-piece mirror having at least four times the collecting area of then existing telescopes. Gemini Observatory today is the realization of that vision. As we move forward with our transition plan, the strengths and unique capabilities of the Gemini Observatory are foremost in our strategic choices. As NSF ponders the future and the strategic choices it must make, we note that the Gemini Observatory fulfills a critical role in the landscape of astronomical tools. We urge the NSF to retain the funding for this facility, and put us on the path to a vibrant future in astrophysical research.

10. Acronyms and Names

The following acronyms and names appear in the preceding sections.

Acronym/Name	Definition
A&G	Acquisition and Guiding Unit
AD	Associate Director
ALMA	Atacama Large Millimeter Array
ALTAIR	Altitude Conjugate Adaptive Optics for the Infrared
ALTAIR Report	Access to Large Telescopes for Astronomical Instruction and Research
AO	Adaptive Optics
AOC-G	AURA Oversight Council for Gemini
ARC	Australian Research Council
ASM	Adaptive Secondary Mirror
AURA	Association of Universities for Research in Astronomy, Inc.
CADC	Canadian Astronomy Data Centre
CCD	Charge Coupled Device
CFHT	Canada France Hawaii Telescope
CFO	Chief Financial Officer
CFP	Cosmology and Fundamental Physics
CTIO	Cerro Tololo Inter-American Observatory
DAS	Data Analysis Specialist
ELT	Extremely Large Telescope
ESPaDOnS	Echelle SpectroPolarimetric Device for the Observation of Stars
F&A	Facilities and Administrative
FAA	Federal Aviation Association
FDF	Facility Development Fund
FLAMINGOS-2	Florida Multi-object Imaging Near-IR Grism Observational Spectrometer-2
FTE	Full-Time Equivalent
FWHM	Full Width at Half-Maximum
GAN	Galactic Neighborhood
GCT	Galaxies across Cosmic Time
GeMS	Gemini Multi-Conjugate Adaptive Optics System
GHOS	Gemini High-Resolution Optical Spectrometer
GFC	Gemini Finance Committee
GHDIS	Gemini High-Dispersion Infrared Spectrometer
GIROS	Gemini Infrared-Optical Spectrograph
GLAO	Ground Layer Adaptive Optics
GMOS	Gemini Multi-Object Spectrograph
GNAOI	Gemini North Adaptive Optics Imager
GNIRS	Gemini Near Infrared Spectrograph
GPI	Gemini Planet Imager
GRACES	Gemini Remote Access to CFHT ESPaDOnS Spectrograph
GRB	Gamma-Ray Burst
GSA	Gemini Science Archive
GSAOI	Gemini South Adaptive Optics Imager
GSC	Gemini Science Committee
HBF	Hilo Base Facility
HIA	Herzberg Institute of Astrophysics
HIRES	High Resolution Echelle Spectrometer
HST	Hubble Space Telescope

IDF	Instrument Development Fund
IFU	Integral Field Unit
IR	Infrared
IRAF	Image Reduction and Analysis Facility
ITAC	International Time Allocation Committee
JWST	James Webb Space Telescope
KBO	Kuiper Belt Object
Keck	Keck Telescope(s)/Observatory
LAN	Local Area Network
LEED	Leading Energy Efficient Design
LGS	Laser Guide Star
LSST	Large Synoptic Survey Telescope
MCAO	Multi-Conjugate Adaptive Optics
MCT	Ministério da Ciência e Tecnologia (Brazil)
MCTIP	Ministerio de Ciencia, Technología e Innovación Productivia (Argentina)
Michelle	Mid-Infrared Echelle Spectrograph and Imager
MIR	Mid-Infrared
MKWC	Mauna Kea Weather Center
MOIRCS	Multi-Object Infrared Camera and Spectrograph
ngCFHT	Next-Generation Canada France Hawaii Telescope
NGO	National Gemini Office
NICI	Near Infrared Coronagraphic Imager
NIFS	Near Infrared Integral Field Spectrograph
NIR	Near-Infrared
NIRI	Near-Infrared Imager and Spectrometer
NOAO	National Optical Astronomy Observatory
NRC-CNRC	National Research Council-Conseil National de Recheres du Canada
NSF	National Science Foundation
NTAC	National Time Allocation Committee
NWNH	US National Research Council report, *New Worlds, New Horizons in Astronomy and Astrophysics*
O&M	Operations and Maintenance
OPD	Observatório do Pico dos Dias
OT	Observing Tool
Pan-STARRS	Panoramic Survey Telescope And Rapid Response System
PhD	Doctor of Philosophy
PI	Principal Investigator
PIO	Public Information and Outreach (Gemini Observatory group)
PIT	Phase I Tool
PSF	Planetary Systems and Star Formation
PyRAF	Python-based version of IRAF
RSS	Really Simple Syndication
SBF	Southern Base Facility
SOAR	Southern Astrophysical Research telescope
SPIE	Society of Photo-optical Instrumentation Engineers
SSA	System Support Associate
SSE	Stars and Stellar Evolution
STAC	Science and Technology Advisory Committee
STEM	Science, Technology, Engineering, Mathematics
STFC	Science and Technology Facilities Council (United Kingdom)
Subaru	Subaru Telescope

T-ReCS	Thermal-Region Camera and Spectrograph
TAC	Time Allocation Committee
TEXES	Texas Echelon Cross Echelle Spectrograph
ToO	Target of Opportunity
UK	United Kingdom
US	United States (of America)
VISTA	Visible and Infrared Survey Telescope for Astronomy
VITRO	Visualisador de Transito Oceanico
VLT	Very Large Telescope
VV	US National Research Council report, *Visions and Voyages for Planetary Science in the Decade 2013-2022*
WAN	Wide Area Network
WFMOS	Wide-field Fiber Multi-Object Spectrometer