AURA Management and Operations of the National Optical Astronomy Observatory (NOAO) and the National Solar Observatory (NSO)

APRIL 1, 2009 THROUGH MARCH 31, 2014

Submitted to the National Science Foundation
December 1, 2007

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TABLE OF CONTENTS: SECTION C

II. THE NATIONAL OPTICAL ASTRONOMY OBSERVATORY

NOAO EXECUTIVE SUMMARY

NOAO is NSF's center for ground-based optical and IR nighttime astronomy. Its mission is to provide broad community access, based on peer review, to a complete and balanced system of state-of-the-art facilities, including telescopes of all apertures, and the data from them. While the correct balance in this mix has been difficult to determine and maintain, NOAO will structure its program and its internal organization in a new way to do this better. The NOAO program will change in the following ways:

- The infrastructure at its existing observatories, KPNO and CTIO, will be modernized to allow better support of users and the deployment of new, high-performance instruments. Access to these facilities for the community will be maximized. Maintenance of the federal capabilities, and access to them, will be a high priority.
- NOAO will work with the community to determine the science-driven, optimum mix of capabilities; and it will attempt to provide these, either through the development of new instruments and observing modes on its own telescopes, or through partnerships with non-federally-funded telescopes. The ultimate result of these efforts will be a complete, robust, and evolving System of ground-based O/IR facilities.
- Gemini is a fundamental element of the System. NOAO is committed to building a strong community of Gemini users and will be a proactive advocate of community interests and access to Gemini.
- Efforts aimed at ensuring community access to the extremely large telescopes will focus on raising community support for such access, understanding and representing community interests to those telescope projects, and reporting on their progress to the NSF.
- NOAO's continued participation in LSST will ensure the broad community return that this project promises. In the operations phase, NOAO will concentrate on supporting community use of the data.
- The programs that provide support or resources for collaborations and partnerships with universities and other observatories throughout the ground-based O/IR System will be gathered into a System Division. This division also will lead planning activities involving the community for the evolution of the System, run programs aimed at providing improved access to needed capabilities, and identify opportunities for making the System more robust and more diverse.
- NOAO's outreach efforts, already successful in a diverse set of educational and public programs, will add two new foci: (1) helping NOAO engage the astronomical community to ensure a continuing dialog about NOAO's program and its evolution, and (2) a renewed and strengthened attempt to address the issue of diversity, including a plan to partner with traditionally black colleges and universities to bring new, talented, minority students into its field.

Along with these changes, NOAO will continue to provide the services that the community expects: operation of observatories, access to a wide array of capabilities and support to allow effective use of them, access to archived data and software tools, and a vibrant outreach program.

1 INTRODUCTION

Humankind's understanding of the Universe has changed dramatically over the last 20 years. Dark energy, precision cosmology, extrasolar planets, galactic archaeology—these phenomena were unknown 20 years ago. Yet all have become fundamentally important to the knowledge of how the Universe works, how it came to be, and where it is going.

At the same time, the ways that researchers study the Universe have expanded dramatically. Uniform surveys of thousands—or even millions—of objects, data mining of archives, and panchromatic information on spatial resolution scales from microarcseconds to degrees allow astronomers to invent new methods of analysis, see new patterns, and make apparent physical connections that would have been impossible before.

One consequence of this change is the synergy among capabilities and techniques. Going to the telescope to make an observation is only part of the story; most breakthroughs in understanding come from combining data—data that represent different wavelengths, times, or resolutions. The relationships between observations can be seen as supporting capabilities, as the complementarity of ground- and spaced-based observations, or as the exploration of the time-domain. But, it is clear that the maximum effectiveness of astronomical facilities comes from being part of a system or suite of capabilities. This system context implies balance among the various capabilities. Small aperture telescopes are better for wide-field observations, while large aperture telescopes are needed for the photon-starved applications. Access must be provided in a scientifically justified, balanced manner.

The idea of looking at astronomical facilities as components of a system is not new. The 2000 NRC report, Astronomy and Astrophysics in the New Millennium, makes the case that for the U.S. community to be competitive internationally, its national suite of public and private ground-based telescopes must be considered as a system—with strategic planning for the System's evolution guided by complementarity and cooperation. (Hereinafter, "the System" applies to the ensemble of ground-based optical/IR facilities and other resources used by the community to carry out research and education in astronomy.) This, then, is a system defined to provide a complete set of capabilities to fulfill the aspirations of the community. NOAO was given specific roles in the decadal survey: to lead the development of strategic planning for the System, to partner with the private institutions to develop and provide access to the facilities needed at all scales, and to represent community interests within these partnerships.

Although NOAO fulfills these roles, the optical/IR community is diverse. It includes educators and researchers at a broad range of institutions: at those with primarily undergraduates, at major research universities, private institutions, and national laboratories. It includes students and teachers at every level, as well as those who are engaged mostly or totally in research. Some are primarily concerned with developing the next generation of cutting-edge capabilities; others are concerned mostly with getting telescope time to further their current research of their current grant. Given limited resources, NOAO managers make choices continually about the balance among the various activities: how much effort to prepare for facilities that might be decades away, how much effort to maintain the current facilities, how much effort to develop the next instruments for the current telescopes? It is clear that this balance must be regularly reassessed.

The recent Senior Review (SR) of NSF-funded astronomy centers observed that the investment at NOAO had moved too far towards the largest, future capabilities. The effect of this on the current facilities is driven by the large cost of those future projects; significant progress could be made only by severely impacting current operations. The reviewers also noted that the NSF could not fund the public share of construction of GSMT rapidly enough to match the current plans of the potential public-private partnerships.

NOAO is responding to the SR recommendations by proposing a program that is guided by (a) a balance among activities that is frequently reassessed using the NSF's criteria of intellectual merit and broader impacts, and (b) a continual dialog with the community through new media and mechanisms in addition to traditional ones. The new program addresses specific concerns expressed in the SR report in three ways:

1. The transfer of resources from the current facilities, Kitt Peak National Observatory and Cerro Tololo Inter-American Observatory, to future large projects—primarily the GSMT—will be discontinued; infrastructure at these current sites will be strengthened and modernized. The partnerships that had allowed NOAO to transfer resources away from the observatories without impacting their continued operation will not be renewed, and the community will regain its access to state-of-the-art capabilities.
2. Activities at NOAO aimed at public participation in a GSMT will be realigned with a realistic expectation of NSF's ability to provide significant funding. These activities will be guided by a management plan approved by the NSF and the private GSMT projects.
3. The entire NOAO program and its evolution will be considered in the context of a national public-private System and a diverse community's related needs and expectations. This will require reaffirming NOAO's community ties, developing new channels for interaction, and strengthening its relationships with non-federal facilities to make the System robust. The NOAO observatories, Kitt Peak and Cerro Tololo, and the U.S. part of Gemini, are the System core.

The System context clarifies NOAO's role and justifies choices. A System optimized for the whole community is balanced so that there is no more redundancy (or gap) than is required to make observations of high scientific merit as judged by peer review. It is balanced in that the division of resources among facilities of different sizes is considered continually; it makes no sense strategically to overdevelop one piece of the System at the expense of another.

NOAO will provide some of the capabilities directly. The community can obtain other capabilities by leveraging non-federal investment. The ongoing discussions that determine this balance will take place both within NOAO and outside, involving all segments of the community. Also, NOAO programs that develop instrumentation, archives, and data analysis tools can be focused broadly on the System, thus adding value throughout.

From this approach, NOAO's mission may be recast as "**providing access to an optimized system of high-performance telescopes of all apertures, and the data from them, for the benefit of the entire community.**" It is important to recognize that NOAO's role is one of leadership. The System is not a haphazard combination of castoff capabilities—all aspects of it must be crafted carefully to provide the community with a complete set of capabilities to use effectively and efficiently.

The following proposal sections describe how NOAO will fulfill this mission, starting with the most fundamental scientific problems that face the community. The technical plan describes the activities of each major program—KPNO; CTIO; NGSC; and the new System Division, which comprises System Instrumentation, Data Products, the GSMT Program Office, and System Development—as well as the LSST and PAEO activities. The management plan that follows explains how these activities will be organized and coordinated. It explains the model for staffing in scientific and technical areas and describes the relationship of the priorities and their evolution to the budget. Finally, goals and metrics for ongoing evaluation are discussed.

2 SCIENTIFIC PROGRAM PLAN

2.1 Scientific Challenges

The variety of capabilities that NOAO supports must correspond to the variety of scientific investigations that the astronomical community wishes to undertake. The design and construction of state-of-the-art instruments takes years; the community must see that the evolution of capabilities to which they have access tracks their aspirations—and not with a lag of years. Thus, NOAO's planning must incorporate an understanding of the current array of unsolved problems in astrophysics and the potential techniques for solving them. At any given time, the breadth of active community research is considerable. The instrumentation falls into generic categories such as optical vs. IR and imaging vs. spectroscopy. Within these categories, characteristics such as field-of-view, multiplex advantage, and spectral dispersion define an n-dimensional array of possible instruments. NOAO tries to provide a set of workhorse instruments that broadly cover the parameter space. Each new instrument aims to cover new ground in some way that is scientifically relevant and in which substantial improvements can be made because of technological advances.

It is easy to list a set of topics that are currently regarded as subjects of interest in the astronomical community: the nature of dark energy; the characteristics of reionization of the universe; the formation and evolution of extrasolar planetary systems; the assembly of galaxies both in a statistical and global sense, and in detail as observed in the Milky Way and its neighbors; the constituents of the solar neighborhood; the growth of supermassive black holes and their relationship to host galaxies; etc. Development of new instrumental capabilities depends on a combination of drivers that includes specific scientific justifications, but also relevance to a number of different topics. For example, for NEWFIRM, the wide-field IR imager, science that was explored and used to set requirements included (a) a search for methane brown dwarfs, (b) probing extincted regions of star formation in nearby molecular clouds, (c) a survey for high redshift clusters of galaxies, and (d) detecting primeval galaxies that emit primarily emission lines.

NOAO's success in providing the needed capabilities can be demonstrated in several ways, including (1) following the evolution of work on a scientific subject through a sequence of observational projects using capabilities provided by NOAO, (2) looking at the diversity and distribution of scientific subjects encompassed by proposals that come in and are granted time in a given semester, and (3) using the literature to identify the long-term and consistent impact of NOAO capabilities. The examples below are not intended to be comprehensive, but merely show that the mechanisms used to define and prioritize new capabilities have allowed the community to use NOAO facilities effectively.

2.1.1 Discovery of Dark Energy

Certainly one of the most exciting and unexpected recent discoveries is the finding that the expansion of the universe is accelerating. This finding came simultaneously from two groups using Type-Ia supernovae as distance indicators: the High-z Supernova Search (High-z SN; Brian Schmidt, PI) and the Supernova Cosmology Project (SCP; Saul Perlmutter, PI). The study that made the use of Type-Ia supernovae as standard candles possible was the Calan/Tololo Supernova Survey (Hamuy, Suntzeff, Phillips, Maza), which used the CTIO Curtis Schmidt telescope to study supernova light curves in detail, and develop a calibration that linked the maximum luminosity with the shape of the light curve. The SCP team used the KPNO Mayall 4-m and 2.1-m telescopes for SN searches and photometry; both teams used the CTIO Blanco 4-m telescope, with a sequence of larger and larger field-of-view imagers developed by NOAO or by instrumentation partners. Both teams made follow-up observations with the optical imager on the KPNO WIYN telescope, in part because that telescope supported a queue-scheduled mode, in which a sequence of observations could be obtained on demand.

NOAO facilities continue to play an important role in studies of dark energy. The Blanco 4-m is the host of the ESSENCE survey project, which is searching for more high-redshift Type-Ia SN in order to constrain the equation of state parameter of dark energy. This project uses the CCD Mosaic Imager, which is the most recently developed wide-field optical imager. The CCD Mosaic Imager will be replaced on the Blanco telescope in 2010 by the Dark Energy Camera, a 2-degree field-of-view optical imager that is being built by a consortium led by Fermi National Accelerator Laboratory to carry out the Dark Energy Survey (DES), a 5000-square-degree multi-band imaging survey of the south galactic cap. The DES, which will use four independent techniques to further constrain the parameters of dark energy, was recognized by the NSF-NASA-DOE Dark Energy Task Force as a Stage III investigation of dark energy.

2.1.2 Assembly of Galaxies

Recent years have seen a change in our view of how galaxies form, in terms of the evolution of the global properties of samples of galaxies and in terms of the fine structure that is observed in the Milky Way. Surveys that have obtained brightnesses, colors, and, in some cases, spectra, for large samples of halo stars have made us realize that the halo is lumpy and heterogeneous, but that correlations among properties provide a picture of infalling streams and tidally disrupted companions.

Spiral Galaxy NGC 5236 (M83) H alpha and continuum image from Survey for Ionization in Neutral Gas Galaxies (sungg.pha.jhu.edu*)*
Photo by: Gerhardt Meurer (JHU), the SINGG Survey Team and NOAO/AURA/NSF

A substantial amount of work at NOAO has been dedicated to stellar populations in the halo and in nearby dwarf galaxies, including the work of Majewski (U. Virginia) and collaborators who have used the wide-field imaging and spectroscopic capabilities of the Blanco 4-m telescope to understand the spatial and kinematic properties of a number of dwarf satellites of the Milky Way. The technique of using particular passbands that minimize contamination allows these researchers to study the populations at locations where the projected surface brightness would be as faint as 31.5 magnitudes per square arcsecond. This technique has been picked up and extended in a different way by Saha (NOAO) and collaborators, who are carrying out *The Outer Limits Survey: Stellar Populations at the Extremities of the Magellanic Clouds* to identify and study stars out to the tidal radii of the Magellanic Cloud.

2.1.3 Analysis of Proposals for Telescope Time

Each semester, NOAO receives approximately 400 proposals for telescope time. These proposals cover the entire range of science that is of current interest to the astronomical community. The proposals are classified as galactic, extragalactic, or solar system, and are further classified within each of these broad areas into a dozen or so different categories so they can be assigned to panels and to lead reviewers. The table below shows this diversity by giving the number of proposals received in each subcategory in the last four semesters:

Panel/Category	2006A	2006B	2007A	2007B
Extragalactic/Active Galaxies	61	49	44	31
Extragalactic/Clusters of Galaxies	26	19	30	20
Extragalactic/Cosmology	16	17	18	22
Extragalactic/High-z Galaxies	40	28	40	24
Extragalactic/Low-z Galaxies	15	26	32	18
Extragalactic/Stellar Populations	15	12	9	17
Extragalactic/Large Scale Structure	7	2	9	3
Extragalactic/Resolved Galaxies	25	21	18	10
Extragalactic/Other	17	14	21	15
Galactic/H II Regions/Planetary Nebulae	6	10	13	8
Galactic/Interstellar Medium	6	6	3	5
Galactic/Low Mass Stars	28	38	41	26
Galactic/High Mass Stars	9	5	11	8
Galactic/Star Clusters	28	18	18	21
Galactic/Star Forming Regions	16	17	5	20
Galactic/Stellar Remnants	32	19	21	20
Galactic/Stellar Populations	21	23	18	20
Galactic/Young Stellar Objects	36	42	34	35
Galactic/Other	7	22	9	18
Solar System/Extrasolar Planets	10	12	17	11
Solar System/Kuiper Belt Objects	9	8	4	6
Solar System/Planets	5	3	5	11
Solar System/Small Bodies and Moons	16	11	10	16
Solar System/Other	0	8	9	0

Note that all fields of research are strongly represented. The distribution of proposal subjects is regularly compared with the range of scientific expertise on the telescope allocation committee panels in order to ensure that growing areas of interest are well covered in the review process.

2.1.4 NOAO's Greatest Hits

One measure of NOAO's success at providing those capabilities that the community wants is the impact of results from the NOAO facilities. Everyone is aware of the results that came from KPNO and CTIO telescopes from the 1960s through the 1990s, such as the discovery and identification of the Lyman-α forest (Lynds), the discovery of flat rotation curves in galaxies (Rubin and Ford), and the investigation of the IR Tully-Fisher relation (Aaronson, Huchra, and Mould). Listed below are some of the most highly-cited studies that used NOAO observations and were published in the last 10 years:

- A majority of all Kuiper Belt objects discovered and cataloged come from the Deep Ecliptic Survey (R. Millis, et al.), carried out on the Mayall 4-m telescope.
- Much of the work on the discovery and exploration of dark energy, as described above, used NOAO facilities. This work continues today and will in the future, as it is a fundamental driver for the Dark Energy Camera. Five of the members of the two groups that won the 2007 Gruber prize are or were on the NOAO scientific staff.
- First direct determination of brown dwarf masses and radii, using an eclipsing double brown dwarf binary system (Stassun, et al. 2006), carried out using Gemini as well as the small telescopes at both Kitt Peak and Cerro Tololo.
- The NOAO Deep Wide-Field Survey, a deep optical and near-IR imaging survey of two 9-square-degree fields, has resulted in more than 60 papers, many by external groups that used the public data releases of NDWFS.
- Most of the observations that provided the basis for the development and calibration of the surface brightness fluctuation method of determining distances to galaxies were carried out on NOAO telescopes (Tonry, Blakeslee, Ajhar, and Dressler 1997).
- Spatially resolved mid-IR maps of young stellar debris disks and evidence of collisional processes driven by embedded planets come from observations made by Telesco and collaborators using the T-ReCS mid-IR imager and spectrograph on Gemini South.

An image of part of the Orion Association taken with the Gemini-North Adaptive Optics (AO) system, Altair, using the Laser Guide Star (LGS) to feed the Near-Infrared Imager (NIRI). This is a composite picture, composed of several images taken in three infrared colors. The blue color is from [Fe II], while the orange color is light from molecular hydrogen (H_2), and these two narrow-band images have been combined with a K-band image. The image is 50 arcseconds across and the resolution is 0.1 arcseconds. The blue knots represent clumps of material ejected from young, still-forming, stars that are plowing through the interstellar medium of the Orion Association and the [Fe II] emission is from hot, shocked gas. The cooler H_2 emission is the bow wake from the ejected clumps.

2.2 NOAO and the Science of the Next Decade

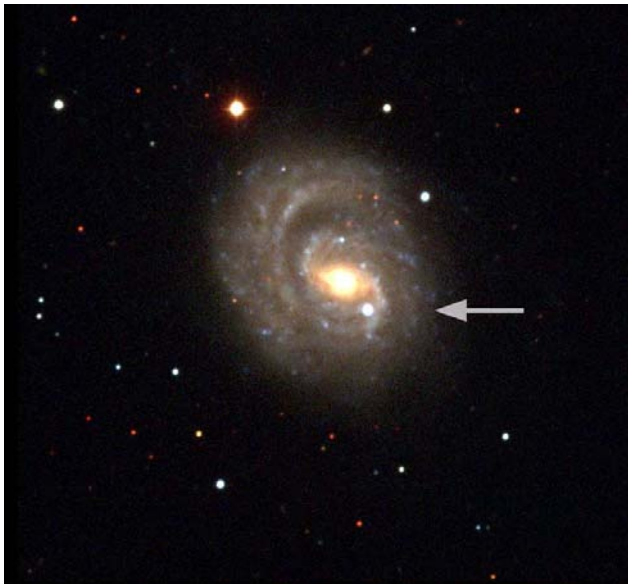
The topics described above, and many other areas of current active research, provide a fundamental context for the NOAO program and the decisions about the balance of capabilities to develop and to offer the community. This relationship is complex: it requires assessing the balance among small programs and large programs, between those that must be coordinated among multiple facilities and those that are simple to carry out, between those that require an array of 1-m telescopes spaced longitudinally around the world and those that require a single 30-m telescope with adaptive optics. It is the challenge of assessing and addressing this balance that is the justification for a national observatory. NOAO's intent during the period of this cooperative agreement is to approach these balances in a new way. The assessment will bring together ideas and acknowledge perspectives from all segments of the community. It will be scientifically justified in the sense of being scientifically balanced; significant attention and effort will be applied to the interests of all who are willing to participate in the discussion. To address these community interests and aspirations will also require a new approach. That approach is what NOAO has termed the System, the public-private partnership to create and make available a complete suite of state-of-the-art capabilities. NOAO's role in this is consistent with both the decadal survey and the Senior Review: *to lead the discussions* through which the community expresses its interests and desires, *to develop a comprehensive and viable plan* for providing the capabilities that will address these community interests and desires in a balanced way, *to provide or initiate some of them* as public facilities, and *to work with the non-federal facilities* to develop and provide access to the others.

Some of the desirable outcomes are obvious: (1) deployment of new, high-performance wide-field optical imaging systems both north and south (Dark Energy Camera and the WIYN One Degree Imager) to assemble massive datasets of high redshift galaxies necessary for studying large-scale structure, the geometry of the universe, and the evolution of stellar populations; (2) development of a network of telescopes that will be able to follow up on time-domain discoveries, including moving solar system objects, variable galactic objects, and transient objects throughout the universe; and (3) high-throughput spectrographs to obtain high-dispersion optical and IR spectra of stars both within the Milky Way and in nearby galaxies to better understand stellar physics processes and the relationships between abundances and kinematics. However, there will never be sufficient resources to provide all useful capabilities, and choices will have to be made about priorities and how to go about providing any particular capability.

2.3 NOAO Scientific Staff

NOAO's fundamental mission is to enable research and discovery by a broad community of scientists by providing access to state-of-the-art facilities, instruments, and software tools—both today and in the future. To do so requires a staff deeply involved in carrying out forefront research as active users and developers of a broad range of instrumentation and software, *sine qua non* for providing knowledgeable advice, guidance, and support to visiting scientists. Moreover, the staff must embody the combination of communications and leadership skills essential to catalyze community efforts to develop a shared strategic vision for the evolution of the U.S. System of telescopes and facilities, and to ensure their broad availability for future users. Finally, because the success of the System depends critically on forging effective public-private partnerships, the staff must enjoy the respect of their colleagues in the university community and major private observatories, and be viewed as desirable and collegial partners in building and operating major instrumentation and facilities.

Over the decades, NOAO has developed a unique scientific culture in which its staff recognizes the necessity of achieving the proper balance of (1) support of visiting astronomers, (2) service to the community via planning efforts and facilitating partnerships, and (3) excellence in research. Essential to nurturing this culture is a management approach that at once ensures that the staff first meets its commitment to institutional service and leadership, roles analogous to the teaching and service missions at peer university institutions, but second, that they are still able to carry out first-rate scientific research. This delicate division between service and research, combined with performance standards matching those of major research universities, is intended to ensure that NOAO scientific staff are the peers of their university colleagues and that they are strongly invested in the research goals of NOAO users, both now and in the future. Recently, this model has been extended to the outreach program, with four Ph.D. astronomers whose area of functional contribution (and research interest) is education.



Major Award for Dark Energy Discovery: *NOAO astronomers Chris Smith and Tom Matheson, and former scientific staff members Nicholas Suntzeff, Mark Phillips and Robert Schommer, were awarded the prestigious Gruber Cosmology Prize as contributors to two scientific teams who simultaneously discovered the "crazy" phenomenon of the accelerating expansion of the Universe, known since by the name dark energy.*

Standards for tenure and post-tenure review for the NOAO scientific staff are matched to the vision of excellence in service, leadership, and science and are maintained at the level of major research universities. NOAO's internal tenure committee also makes innovation an additional criterion for tenure, thus emphasizing as well the importance of continuous improvement of NOAO's research facilities. AURA's Observatory Council and Board of Directors closely monitor the application of these standards, in service to NOAO's institutional roles.

Examples of the success of the staff in balancing this "triad" of responsibilities are (1) NOAO's development of state-of-the-art instrumentation in partnership with other institutions (e.g., DEC, ODI, and NEWFIRM); (2) successful launching of the TSIP program—a cornerstone of the U.S. System; (3) development and implementation of programs to enable planning of joint ground- and space-based observing programs with Spitzer, Chandra, and HST; (4) development of a successful program through which middle school and high school science teachers undertake cutting-edge observational research projects to enhance their knowledge of astronomy and physics, as well as their leadership skills; (5) successful initiation of a survey opportunity that enables research teams to carry out frontier programs of scale, and provides the community with access to rich, multiple-use databases as a result; (6) launching and support of science working groups for the GSMT and LSST projects; and (7) launching of the public-private partnership to construct LSST.

3 TECHNICAL AND FACILITIES PLAN

3.1 A New Context for the NOAO Program

The ground-based O/IR System consists of the combination of public and private ground-based O/IR astronomy research facilities. What makes them a *system* is not merely the fact that they add up to greater resources than any subset of them; it is the fact that they are not copies of each other, but are diverse and complementary. Thus, to the extent that access is shared and strategic planning considers the System as a whole, a broader range of instruments, some “workhorse” and some “niche,” can be deployed, a broader range of observing modes—classical, queue, and remote—can be made available optimally, and a broader range of partnerships can be developed. This concept provides an opportunity for NOAO to lead a community discussion aimed at a positive evolution of the System, a responsibility assigned specifically in the AASC report and encouraged by the Senior Review. It also provides a framework for understanding the NOAO program and gives guidance for planning within that program.

The NOAO observatories, KPNO, CTIO, and NGSC, are the core of the U.S. System. Their facilities are available to the greatest extent possible to the community, and they develop new capabilities and provide support as a direct consequence of the aspirations of the community. However, decisions about the evolution of these observatories must be made through a discussion including and concerning the entire System, so as to take maximum advantage of what other facilities are providing or could provide.

Many of the other NOAO programs are inherently broader than the observatories in terms of their justifications and their planning. Instrumentation, data management, and the telescope time allocation process must be aimed at making the entire System stronger. Although they have a direct responsibility for supporting the other parts of the NOAO program, they also are expected to partner with other institutions within the System to improve their capabilities.

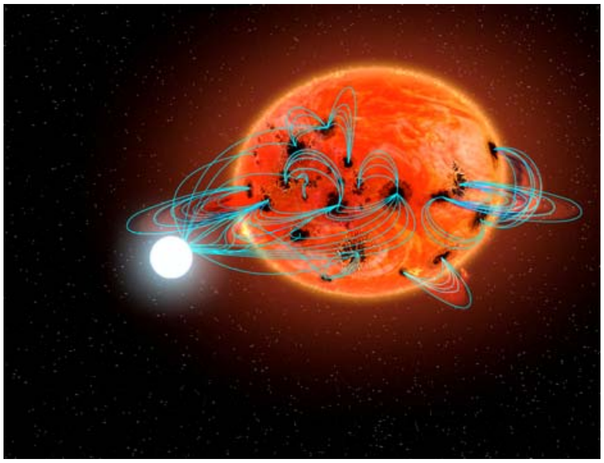
3.2 CTIO and KPNO, Cornerstones of the System

3.2.1 *Success in the Past and Future*

For nearly 50 years, the federally funded observatories have been providing the facilities used by the community for groundbreaking research and the training of the next generation of astronomers and astrophysicists. The national observatories began with KPNO and CTIO, and these facilities remain cornerstones of the System. Alone or in combination with other ground or space-based observatories, the capabilities at KPNO and CTIO have enabled such research as the discovery of dark matter and the recognition of the important role dark energy has in determining the ultimate fate of our Universe. NOAO facilities have provided the data and the opportunities for transformative basic research—research that changes our fundamental understanding of the Universe. Small and mid-sized telescopes are the facilities of choice for many kinds of observations—for example, those that aim to sample the time domain, or require wide fields of view, or wish to study large samples. Furthermore, unique capabilities are often enabled by telescope designs or operating modes not easily implemented on larger telescopes.

CTIO and KPNO continue to have a future in basic fundamental astrophysical research. Their 4-m telescopes are being equipped with modern near-IR (NEWFIRM) and optical (ODI, DEC) wide-field imagers. These imagers will enable diverse programs ranging from ambitious large-scale surveys that follow the paths established by the NOAO Deep Wide-Field Survey, the Deep Lens Survey, or the Super-Macho Project to smaller scale programs that still yield important results that are produced by NOAO's facilities alone.

The CTIO and KPNO telescopes are also platforms for collaborative development of new technologies that will further all astronomical instrumentation. Recent examples include the first cryogenic multi-object near-infrared spectrograph (FLAMINGOS, with the University of Florida) and other instrument testing technology for space and ground-based applications (e.g., IRMOS, STScI and Goddard, near-IR spectrograph testing technology for JWST). This program of instrumentation collaborations will continue with current projects (WHIRC, near-IR imager for WIYN; ODI, optical imager for WIYN; DEC, wide-field optical imager for CTIO; and many more) and with new projects in the future.



Interactive Binaries Show Signs of Induced Hyperactivity: *Astronomers studying highly energetic binary stars called polars have obtained the first observational evidence that the intense magnetic fields produced by the white dwarf half of the interacting pair can induce flares, sunspots, and other explosive activity in its otherwise low-wattage, low-mass partner. (NOAO Press Release 07-01)*
Image Credit: P. Marenfeld and NOAO/AURA/NSF

The same capabilities that enable stand-alone optical and near-IR ground-based research also enable collaborative, multi-observatory (often multi-wavelength) investigations with other ground-based facilities and with NASA's Great Observatories (HST, CXO, Spitzer) and other future missions of NASA and ESA (Herschel, GLAST, WISE, and many more). Plans are in development to provide improved spectroscopic capabilities at CTIO and KPNO, particularly those that might be well suited to following up wide-area imaging surveys (LSST or Pan-STARRS) in a rapid manner. The smaller telescopes, when equipped with modern instrumentation, have similarly bright futures supporting the programs of their larger sisters. CTIO and KPNO will continue to work with SOAR, WIYN, and the tenant observatories to maximize NOAO's contribution to the System as it grows.

The geographic distribution of facilities plays an important role in the optimal strategy for development. NOAO inherently provides access to both northern and southern skies through its two observatories. Similarly, Gemini's north-south symmetry addresses the community's desire for complete coverage. Relationships to other facilities argue for deploying certain types of capabilities preferentially in different locations. For example, the Dark Energy Survey aims to get photometric redshifts for clusters found by the South Pole Telescope; ALMA will be located in the Southern Hemisphere, but the majority of very large U.S. telescopes are located in the Northern Hemisphere. The System needs to be able to optimally support and take advantage of all these facilities. Both KPNO and CTIO must be key components of the System.

3.2.2 Restoring and Upgrading CTIO and KPNO

Ground-based telescopes have a long lifetime; they can be continually renewed through new, state-of-the-art instrumentation. However, this renewal requires a number of activities. Not only must new instruments, often involving new technology, be developed and deployed, but the infrastructure of the telescopes and the observatory must also be kept current. Control systems must be modernized. Computers and network hardware and software must be kept current. Labs to maintain modern equipment must themselves be kept up-to-date. Human skills and expertise must also be kept modern. Support staff must be able to assist observers with new instruments and diagnose problems quickly.

Kitt Peak National Observatory and Cerro Tololo Inter-American Observatory are in the process of renewing their infrastructures. The general goals of this renewal are to make these facilities more effective and efficient, scientifically and operationally; to provide the community with modern observatory infrastructure that will encourage more non-federal telescopes to be built on these sites and to be operated more cheaply; and to allow evolution of the System capabilities at apertures of 4 meters and below. Along with the aspects of this modernization that come directly from the experience of operating an observatory, KPNO and CTIO are also developing programs that will provide a greater level of technical support to observers and a set of new capabilities that will seek to address the needs of the community.

3.2.3 Protect the Sites and Renew the Basic Infrastructure

CTIO and KPNO were both founded on excellent sites; they have good weather, good seeing, and dark skies. During the past operation of these observatories, the weather has remained excellent and NOAO has managed to actually improve the delivered image quality of its telescopes. Remarkably, the growth of communities near both Kitt Peak and Tololo in the last 10 years has not significantly degraded how “dark” the sites are when compared to data 10 or 20 years ago. This is because of active work by AURA and NOAO to work with local, state, and national agencies to protect the dark skies on which NOAO depends. This work will continue during the next five years. Continued investment in these sites requires continued work within the communities in which they operate in order to protect the quality of the sites.

Both CTIO and KPNO are mini-towns on mountaintops. They provide basic services to both their own facilities and to many tenant observatories. Basics including potable water, power, food, shelter, and initial emergency response are all provided by NOAO. To continue such services efficiently, both CTIO and KPNO will have to carry out an extensive program of repair and renewal of buildings and physical plant. Work has already begun at both observatories and will continue over the next five years. In addition to basic repairs, improvements will also be undertaken. These will include modern suites of site monitoring equipment (DIMM, all-sky camera, etc.) at both sites, instrument-handling facilities (including clean rooms) to aid in the care of instruments for all the telescopes on these mountains, and upgrades of the CTIO mirror aluminizing facility as needed. All of these improvements will aid not only the CTIO and KPNO telescopes, but all the telescopes on the mountains.

3.2.4 Modernize the Telescopes and Instruments

It is well recognized, most recently by the NSF Senior Review, that the telescopes and instruments of CTIO and KPNO need to be modernized to the state expected in the 21st century. This work has begun with plans for a new telescope control system for the Blanco 4-m telescope and with new detector controller systems (MONSOON) under active development with the goal of upgrading existing instruments at all the telescopes at both observatories over the next five years. Detailed planning takes into account the funding profile, the availability of manpower, and the effect of the upgrade on the scientific productivity of the facility. NOAO's goals include upgrades to all the major telescopes (Mayall 4-m, Blanco 4-m, and KPNO 2.1-m) as well as new controllers and guiders for existing instruments. The basic computer infrastructure for the telescopes and the observatory sites also is scheduled for upgrades, as the next generation of new instruments will require an improved environment in which to work if they are to reach their full potential.

These modernization activities—both of site infrastructure and of the telescopes—have already begun, using resources that were made available as a result of program changes following the Senior Review. The improvements that could be accomplished most quickly included the purchase of spare parts (e.g., shutter drive components) that would be long lead-time replacement purchases and replacement of expensive equipment (e.g., road maintenance equipment) that was nearing the end of its useful lifetime.

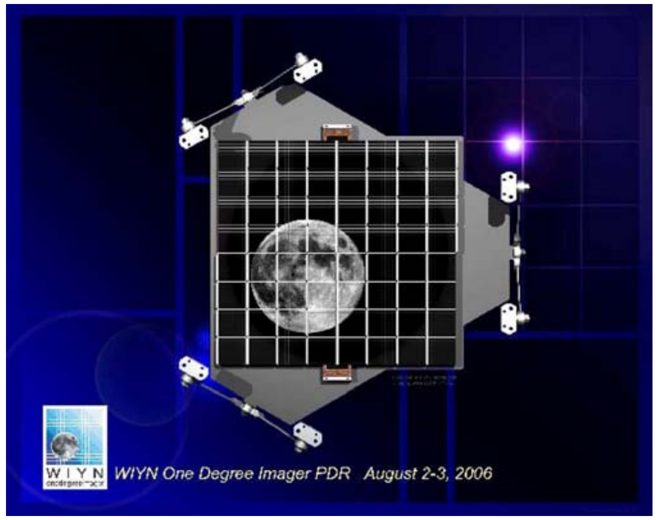
The plan for modernization in the next few years will be comprehensive. Examples of some of the most significant improvements are listed in the table below.

Location	Item
Blanco 4-m telescope	Control & computer room upgrade
KPNO mountain infrastructure	Water plant modernization & distribution line replacement
KPNO	Bus replacement
KPNO and CTIO	Vehicle renewal (8 cars, CTIO) Vehicle renewal (6 trucks, KPNO)
KPNO and CTIO mountain infrastructure	Cleanroom in Blanco 4-m building Instrument Handling Facility (including cleanroom)
Blanco 4-m telescope	Telescope Control System
Blanco 4-m telescope	Primary Edge Supports
KPNO and CTIO telescopes	Monsoon Controllers (4, CTIO) Monsoon Controllers (KPNO)
KPNO and CTIO telescopes	Rotator/Guider Upgrade (Blanco) Upgrade Guiders (KPNO)
KPNO 2.1-m telescope	New Observing Platform, RA/Dec Cable Wraps, HVAC System refurbishment
WIYN 3.5-m telescope	Upgrade Instrument storage, implement folded-Cass port
Mayall 4-m telescope	Update Control Room, Refurbish Dome Trucks and Shutter, Refurbish RA/Dec drives

Studies are also underway at both CTIO and KPNO to identify instrument-telescope combinations that could be offered to remote observers, enabling new types of observing opportunities in the future. Automating some instrument calibration steps and providing improved basic data reduction pipelines are also upgrades being considered. Restoring queue and/or limited service observing are capabilities that, pending consultation with the user community, might be reintroduced to NOAO's facilities. The combination of telescope/instrument upgrades with new observing modes is anticipated to increase the scientific productivity of NOAO's telescopes and broaden their use in education.

3.2.5 Bringing New Instruments to CTIO and KPNO

The telescopes of CTIO and KPNO will need new instruments to continue to fulfill the aspirations of the community. A number of instruments are currently in various phases of development, all of them in partnership with external groups. For KPNO, the wide-field IR imager NEWFIRM is being commissioned. This instrument will be shared between the Mayall and Blanco telescopes on a cycle of approximately 4 years. WHIRC, the WIYN High Resolution IR Camera, is also beginning its commissioning. ODI, the WIYN One Degree Imager, is planned for delivery in 2009. The Dark Energy Camera is expected on the Blanco telescope in 2010; and several instruments for SOAR, the SOAR Adaptive Module (SAM), the Goodman Spectrograph, and the Spartan IR camera, are all nearing completion. Following these, it is anticipated that the discussions and report of the ReSTAR committee will have a major bearing on future instrument development for the NOAO telescopes.



The WIYN One Degree Imager, with its combination of wide field-of-view and high resolution, will provide U.S. astronomers with a uniquely powerful capability for a wide range of optical imaging projects.
Image Credit: WIYN and NOAO/AURA/NSF. Courtesy of Indiana University.

NOAO will continue to work with institutions that want to bring new instruments to its telescopes. In the past, such activities have provided many researchers not only the opportunity to develop innovative instrumentation, but also access to new capabilities in a timely manner. Past successes at CTIO include: BTC, OSIRIS, ANDICAM, Ohio State 4K Imager, and Rutgers Fabry-Perot. KPNO successes include: Goddard Fabry-Perot, FLAMINGOS, IRMOS, Exoplanet Tracker (ET), ONIS, and OPTIC. NOAO will continue to make its telescopes inviting platforms for such innovative instrument development by the community.

3.2.6 Renewing the NOAO Staff

CTIO and KPNO need to have adequate scientific, technical, and administrative staff to optimize the science output of the observatories. The scientific staff lead and monitor the efforts to keep telescopes and instruments operating correctly; they provide user documentation so that visiting and remote observers can plan and carry out their observations efficiently; and they need to be familiar with data pipelines and reduction techniques so that they can respond to any issues that observers have in reducing their data. They also monitor the end-to-end data management system to ensure that all data flowing into the NOAO Science Archive, including associated databases such as the records of the environmental conditions, will be of value for future researchers. In addition, they also identify and promote instrument and telescope upgrades and new modes of observing, interacting with the community in this process. NOAO scientists, who have active research programs that use the CTIO and KPNO telescopes, and others in the U.S. system, facilitate these tasks.

An NOAO scientific staff member since 1995, Buell Jannuzi was named to a five-year term as Director of Kitt Peak National Observatory in March 2007. His main scientific interests are the formation and evolution of galaxies, the large-scale structure of the Universe, and the physical processes that produce active galactic nuclei.
Image Credit: P. Marenfeld and NOAO/AURA/NSF

It is clear that the level of user support at both observatories has dropped off in recent years, and one of the responses to the call for increased and improved access will be to restore it. In order to do this, CTIO will increase the scientific staff devoted to telescope operations support from the 2.5 FTE at present to 5.5 FTE, in order to return to the level of support needed to operate a state-of-the-art facility. KPNO will increase its staff from the FY06 value of 1.75 FTE to 5.0 FTE by 2010. Major areas of responsibility that will be recovered include restoring dedicated telescope and instrument scientists. These "new" staff will come from a combination of changes in responsibility for existing staff and some new hires, who will replace staff lost to retirements and departures over the last few years.

The technical staff operate the telescopes, set up and check the instruments following standard procedures, and respond to faults. A small staff is based on Tololo and Pachón, with operators and some engineering staff providing 24/7 coverage via a shift system. Some technical staff commute to the mountains daily on a Monday–Friday schedule, while specialist support and extra staff in the La Serena-based ETS division provide technical back up. The efficiency of support provided by the technical staff is maximized if equipment is modern and well maintained. Thus reliable equipment may allow work schedules with periods of lower support (e.g., some technical staff available on weekends by call-out only) that are more cost-effective than continuous 24/7 backup. At the present time, the SOAR telescope is the only CTIO-operated telescope that has demonstrated sufficient reliability to allow such a mode (also used at Gemini), and that in a phase with a limited instrument complement (SOI and OSIRIS). The Blanco and the small telescopes on Cerro Tololo will be evaluated for this mode of operation following the maintenance and other upgrades tabulated above.

At Kitt Peak, engineering and technical staffs are based in Tucson and commute to the mountain to perform maintenance, repairs, and upgrades during daytime hours for both KPNO and NSO telescopes. Limited technical assistance is available into the early evening.

The technical staff devoted to support of telescope operations has been cut back at both CTIO and KPNO in recent years for budget reasons. At CTIO, the support level will be increased by devoting more manpower from the ETS group to telescope operations, by some extra hires in critical areas, and by some structural changes in the Telops division. The retirement of several staff over the next few years will facilitate these changes. As an example, new operators for the Blanco telescope will have extra training to enhance their ability to be first responders to problems, in addition to their first priority, which is to operate the telescope and ensure safety of the equipment and those using it. At

KPNO, the technical and engineering staff will increase in order to be able to respond to the challenge of carrying out the modernization and improvement projects envisioned in this proposal. By the end of FY08, KPNO will have increased the number of electronic maintenance technicians from three to four, of instrument technicians from four to five, added an additional electrical engineer, and added 0.5 of an FTE of mechanical engineering.

The steps outlined above will allow the training of the next generation of observatory staff, while continuing to operate the facilities at a high level of performance. The renewal activities will provide exciting opportunities for the NOAO scientific staff to reengage with both CTIO and KPNO and improve the ability of these observatories to meet the needs of the large user community.

3.2.7 Renewing and Developing Major Collaborations

In 1995, the WIYN Observatory began science operations, and it has become the example of how successful partnerships between NOAO and universities can be. With its superb image quality and wide field, the WIYN 3.5-m telescope is the intended platform for the One Degree Imager, an innovative wide-field imager equipped with orthogonal transfer CCDs and capable of delivering 0.4-in images on a routine basis. Scheduled for deployment in 2010, this new instrument is a demonstration of the kind of state-of-the-art capability that can be provided to the community through partnerships between NOAO and universities. During the term of this proposed renewal, the WIYN partnership agreement will be renewed (2010), and KPNO and NOAO will be working to continue this productive partnership in the future.

The SOAR 4.1-meter telescope in Chile is completing its commissioning phase. Thirty percent of the time will be available to proposers through NOAO.
Image Credit: M. Urzúa Zuñiga/Gemini Observatory

The SMARTS (Small and Moderate Aperture Research Telescope System) Consortium, of which CTIO is a member and retains 25% of the telescope time for the community, has operated the four small CTIO telescopes since 2003. The present agreement flexibly allows members to join and leave and operates on a year-by-year basis. The suite of telescopes and instruments has enabled much community science, by offering reliable equipment at an excellent site, with a wide variety of available observing modes. To be successful, SMARTS requires significant contributions to management, scheduling and control of night-night operations, control of queues, etc., preferably by a core of longer-term consortium members. In addition, it needs sufficient consortium members to be financially viable. CTIO supported SMARTS at a low financial level for its first year of operation (this provides more time to the NOAO community) and should be prepared to do the same in the future if need be, but, in general, NOAO’s contribution is merely the telescopes themselves. The long-term core of SMARTS consortium members were, prior to the formation of the consortium, major users of the small telescopes, and the consortium model has been an effective way to achieve a balance between the dedicated access for a few significant users of these capabilities and the more variable and diverse access of the broad community.

NOAO is working to develop new major partnerships in which it leverages the strengths of CTIO or KPNO. The Dark Energy Camera (DECam) is being built by the Dark Energy Survey (DES) Consortium, of which NOAO is a member. In exchange for the instrument, the consortium will conduct the DES using 30% of the Blanco time for five years, starting in September 2010. This major new facility, available for use by the community when not being used by DES, will be capable of a wide variety of science programs, particularly if the SDSS filters that will be delivered with the instruments are complemented with others (e.g., narrowband emission line filters). NOAO will conduct workshops prior to DECam's delivery to motivate the user community by discussing the instrument capabilities and planning science projects. Synergistic activities with other instruments (e.g., NEWFIRM) will also be an important topic for discussion.

3.2.8 Integration of Research and Education

CTIO and KPNO both play major roles in post-graduate, graduate, undergraduate, and pre-college astronomy education. Their facilities are open to all, based on merit, and are frequently used by post-graduate and graduate student lead programs. CTIO and KPNO provide expert support for these programs from inception through analysis of their data. Undergraduates frequently accompany guest observers from their home institutions, gaining experience in astronomy by assisting with their mentor's research program on the telescopes. Both CTIO and KPNO run successful research programs for undergraduates and have worked with the PAEO to provide resources for the many teacher and pre-college student programs organized by PAEO.

Public outreach and education in Chile is focused on support of CADIAS (Centro de Apoyo a la Didáctica de la Astronomía), which has an active outreach program thanks to fundamental support from NOAO and Gemini. La Serena municipality and government grants also support the program, providing a well-levered use of NSF funds. (See the PAEO section for more on this topic.)

All the international observatories in Chile fund the OPCC (Oficina de Protección de la Calidad del Cielo), which is part of the Chilean Environmental Agency that works with government and local authorities on light pollution. Management and scientific support is provided by CTIO. CTIO has also provided surplus equipment, technical and scientific advice, and occasional seed funding to help several small local observatories, schools, and municipalities to become functional. The first of these efforts (Mamalluca near Vicuna) initiated astro-tourism in Chile. Generally this help is highly leveraged, and a very effective way of raising the profile of astronomy among the general Chilean public, which in turn is an aid to the effort of maintaining into the future the pristine skies presently enjoyed by the observatories.

3.3 NOAO Gemini Science Center (NGSC)

Just as KPNO and CTIO form the nucleus of the mid-sized part of the U.S. ground-based O/IR System, the NOAO Gemini Science Center (NGSC) provides community access to the large telescope part. NGSC is the gateway for the U.S. use of the International Gemini Observatory. The Gemini Observatory offers the U.S. astronomical community significant amounts of time on twin 8-m telescopes, with full-sky coverage from the two Gemini sites. Each of the Gemini partners (U.S., U.K., Canada, Australia, Brazil, Argentina, Chile, and Hawai`i) maintains a "National Gemini Office" (NGO), with each NGO being responsible for managing that partner's share of observing time on the Gemini telescopes. As the U.S. NGO, NGSC provides user support, from the preparation of observing proposals, all the way through to helping users implement their approved programs on the telescopes, as well as offering help in data reduction and some analysis. In addition, NGSC provides input to the Gemini Observatory that comes from the U.S. community perspective and involves science planning, instrument development, and operations support. During the period covered by this proposal, NGSC will continue its community support and liaison activities, as well as incorporate into its liaison activities a broad context that acknowledges the relationship between Gemini capabilities and those elsewhere in the U.S. system. Representing the U.S. community, NGSC will be a strong and proactive advocate of their interests and access to Gemini.

The primary liaison conduit between the U.S. community and Gemini includes a number of advisory committees that NGSC links together. U.S. interests in Gemini and how its capabilities relate to the rest of the System flow from the NOAO Users' Committee, through the NOAO Gemini Science Advisory Committee, on to the international Gemini Science Committee. This formal linkage is supplemented by informal relationships between the NGSC and international Gemini staff. The efforts at liaison described above were supplemented during the first half of 2007 by a direct survey, conducted by NGSC, of the U.S. community on their views concerning the future of the Aspen instrument program, along with any comments that they might have about Gemini.

Because Gemini is an international collaboration and includes partners with different resources and interests, the capabilities that it highlights reflect compromises among the various communities. Thus, while it is the single large facility to which the entire U.S. community can provide input, that input is diluted by the need to engage all the partners. Thus, it is necessary that NGSC, which gathers and advocates the input, be proactive and negotiates effectively to ensure that some large fraction of the Gemini capabilities address the needs of the U.S. community specifically. NGSC uses the various interactions, input, and forums described previously to ensure that the Gemini leadership remains sensitive to the U.S. view of Gemini as part of the larger integrated System that is available to the U.S. astronomical community. In the near-future, NGSC will continue to explore ways to increasingly engage U.S. users in all issues relating to the role of Gemini within the large framework of the System.

NGSC's goal is to maximize U.S. community access to the Gemini capabilities and to ensure that the capabilities evolve in a way that addresses the U.S. community's needs as closely as possible. The current Gemini operations agreement ends in 2012, and NGSC will be a proactive advocate for U.S. interests in discussions leading to renegotiation of that agreement.

3.3.1 Science Direction

The two Gemini telescopes each host a diverse set of instruments that include imagers and spectrographs, as well as an operational laser guide star adaptive optics (LGS AO) system in the North and another being deployed in the South in 2007 with multi-conjugate capability. The wavelength range covered by the current instrumentation also spans a very broad range in wavelength, from ~4000 A to the mid-IR (out to ~25 μm). Because of these broad capabilities, the NGSC staff must be well balanced across all ground-based wavelengths and include people with expertise in spectroscopy, imaging, and AO.

New observing capabilities will be coming on line at the Gemini telescopes at a rapid pace for the next several years. These include the Near-IR Coronagraphic Imager (NICI), a multi-object IR spectrograph (FLAMINGOS-2), and a multi-conjugate adaptive optics (MCAO) system for the South that will provide a 2-arcminute corrected field for the Gemini South AO Imager (GSAOI), as well as FLAMINGOS-2. The first of the so-called "Aspen" instruments, an extreme coronagraphic imager (the Gemini Planet Imager-GPI), is being built and planned for a 2010 deployment. Additional Aspen instruments may include a precision radial velocity spectrometer (PRVS) working in the IR H-band, or a wide-field multi-object spectrometer (WFMOS). NGSC continues to maintain the ability to support all of the planned new capabilities, but this requires the efforts of a team of astronomers with necessarily diverse skills and expertise. The range of skill sets currently represented within NGSC must not be allowed to degrade in order to continue to push Gemini's increasing scientific productivity as it evolves into a mature astronomical observatory.

In addition to the everyday NGSC support required to help move Gemini's near-term evolution towards its status as a more mature facility, the observatory's rapidly increasing observational capabilities, coupled to its international character, are two strong assets that are available to the System and will provide knowledge and experience that will be utilized in future projects. Gemini's working model provides a natural training ground for NOAO staff to learn new observational techniques, technologies, and instruments, all within an internationally partnered setting. In every new capability noted above, NGSC staff are deeply embedded in operational planning, commissioning, and support. They are also involved in upgrading the Gemini Web pages, as well as working with the observatory on data reduction pipelines. In these roles, NGSC staff work closely with Gemini staff and travel frequently to both sites.

It is virtually certain that the next decade's new, large astronomical endeavors will be both partnered and international. The NGSC mission within the NOAO/U.S. System is currently providing the community with a group of astronomers who are being seasoned in just such an environment.

3.3.2 User Support

The core support that is necessary to utilize the Gemini telescopes efficiently and effectively rests fundamentally on numerous interactions between the support astronomers and the user community. The main tasks for NGSC core support follow:

Helpdesk Requests: This is a Web-based communication tool between the Gemini users and various NGO and Gemini staff with specific expertise. Questions are directed, based on their classification, to the most knowledgeable individual for that particular type of question.

Technical Help in Preparing NOAO Proposals: NGSC offers U.S. Gemini proposers help in checking their proposals before submission, primarily from a technical point of view.

Technical Reviews of all Gemini Proposals Submitted to NOAO: All Gemini proposals to the NOAO Telescope Time Allocation Committees (TAC) (220–240 per semester) require a technical review, which is carried out by the NGSC staff each semester. Because of some multi-instrument proposals, the number of technical reviews to be done is close to about 300 per semester.

Phase II Preparation: This is the major part of Gemini support from NGSC over the course of a year. Each semester about 90–100 U.S. programs are placed into the Gemini queue. The "Phase II" preparation is a file that contains all of the commands and notes needed to carry out the particular observing program. This file is loaded into the telescope and instrument controllers, after which the desired observations are then executed. Any mistakes that slip through NGSC or Gemini scrutiny can result in lost telescope time and the program possibly not being executed. Some difficult Phase IIs can consume a week of effort on the part of an NGSC astronomer and some just a few hours, but the average is between two and three days of effort.

The fact that Gemini has evolved into a nearly 100% queue-based observatory has honed specific user support skills within the NGSC staff that will be useful in a broad and ever-evolving U.S. System of ground-based facilities. All NGSC staff members are experienced observers, all have worked with Gemini programs of their own, so the support of queue-based programs necessitates that they develop the skills to help the PIs first define and then "flesh out" sometimes very complex observing programs, all done remotely. These particular skills that NGSC has acquired in managing the PI inputs to a large queue are a resource that can be tapped by NOAO, as a whole, in possible future plans to use System telescopes in alternative modes of operation. Also, it is possible that some of the next-generation ground-based facilities that will be supported by NOAO for the U.S. community will be queue-driven to some degree; in which case, NGSC already will have extensive experience in this type of observing support.

3.3.3 Operations Support

The operating agreement for Gemini continues through 2012, so almost certainly it can be counted on that the current model of "distributed support" among the partner NGOs will continue. The oversubscription demand on Gemini from the U.S. community seems to be running nearly flat for the last 2 years at a level of 3.5–4.0. This demonstrates strong interest from the U.S. community in the Gemini telescopes, and argues that an increased level of access to Gemini is desirable.

The scientific staff assigned to operationally support the U.S. community of Gemini users consists of a "team" whose astronomical knowledge and skills span the broad range in wavelength over which Gemini instruments operate and encompass all of the diverse set of Gemini instruments and observational capabilities at both sites. The NOAO users have embraced the availability of queue observing at Gemini and the two telescopes have evolved into a unique facility with full-sky (dual hemisphere) coverage that is capable of supporting 100% queue observing (if so requested by the users). This evolution to a 100% queue has come about in direct response to user demand. To effectively support the NOAO Gemini users, the NGSC staff must be proficient with the particular instruments that they support, as well as have a deep understanding of how Gemini carries out the observing programs and how their organization functions. NGSC thus requires that each of its astronomer visit one Gemini site per semester, observe with the Gemini astronomers over several nights, and spend some time visiting the particular Gemini headquarters.

3.3.4 Instrumentation and Development

The current observing capabilities at Gemini are evolving quickly, with the two most imminent deployments being managed by NGSC. The first of these projects, the Near-IR Coronagraphic Imager (NICI) was built in Hawai`i by Mauna Kea Infrared and has just gone on Gemini-S for engineering tests and commissioning. The second project, FLAMINGOS-2, being built at the University of Florida, will undergo acceptance testing within a few months and will be delivered to Gemini-S in late 2007. NGSC manages and supports these projects through the efforts of the NGSC director and a single engineer (who devotes one third of an FTE to NGSC).

The plan for the next generation of Gemini instrumentation was defined by a conference of the Gemini partners held in Aspen, Colorado in June 2003. Some of these instruments are in study and design phases now, and by 2010, the first, the Gemini Planet Imager (GPI), will be deployed. An NOAO engineer has been contracted by Gemini to monitor, for Gemini, the progress of this large project ($19M plus a $7M contingency). Within a few months, NOAO will have a better idea of what other instruments will be added as a result of the Aspen process: probably either the Wide-Field Multi-Object Spectrograph (WFMOS) or the Precision Radial Velocity Spectrometer (PRVS), or possibly both. Three NGSC staff astronomers are involved in the scientific planning for the WFMOS team that is being led by the Anglo Australian Observatory (AAT). If the AAT team is selected and if WFMOS proceeds forward, then NGSC will be deeply involved in this challenging endeavor. In addition, WFMOS would be deployed on, and in collaboration with, Subaru bringing yet another level of complexity to Gemini operations.

3.3.5 Building the Gemini Community

A major task of NGSC is to inclusively engage the U.S. community in current Gemini issues, observing opportunities, and science results. In addition, NGSC is a strong advocate for the U.S. within the Gemini partnership. In terms of aperture times the amount of time available, Gemini represents the largest single piece in the System that is managed by NOAO. It is not only a major resource, but also a unique one, as the only full-sky coverage 8-m class observatory that is capable of nearly 100% queue observing. Maintaining an active and scientifically productive user community is perhaps the single most important task for NGSC. In order to carry this out, communication with the users is critical. This communication is carried out via a number of channels, which include:

NOAO/NSO Newsletter: Each issue contains an "NGSC Section," and we endeavor to use this as another means of keeping the U.S. community informed about what is happening at Gemini.

Presence at AAS Meetings: NGSC maintains a significant presence at winter AAS meetings by sponsoring a booth, along with a number of staff present. In addition to answering general questions, we are able to provide realtime Phase II support at these winter meetings.

NGSC Web Site: This site (*www.noao.edu/usgp*) contains up-to-date information about the Gemini Observatory, such as information on user support, telescope instrumentation, schedules, etc.

Gemini-North with its Laser Guide Star (LGS) system in operation. The exposure time for this picture was one minute and was taken during commissioning in July 2006.

Gemini PIO Working Group: The NOAO Associate Director for PAEO is an active member of the international Gemini PIO working group, including coordination of 6–8 press releases per year and joint educational outreach at the I'miloa center in Hilo and the CADIAS center in Chile.

Within the larger context of the System, NGSC is working with all of NOAO in planning ways that U.S. users can become more engaged with Gemini and to fully embrace it as one of their most powerful and flexible astronomical facilities. NGSC currently communicates through the Newsletter, the NGSC Web site, and attendance at AAS meetings, but it would be beneficial to go further. Possibilities include, for example, a concerted effort to give talks about NOAO and the System (including Gemini) on a continuing basis, or sponsoring visits by both astronomers and graduate students to either Tucson or the Gemini sites to interact with the Gemini and NGSC staffs. As part of these visits, NGSC staff could also run small workshops on particular instruments and their required data reduction. NGSC also intends to work with PAEO staff on short tutorials that would be made available via audio and video podcasts, and similar options to provide training "on demand." NGSC has already embarked upon an effort to improve the Web site, with more detailed and focused information on observing with Gemini, as well as keeping this information up-to-date by semester.

3.4 NOAO System Division

Casting NOAO's program in the context of the entire System of ground-based O/IR capabilities motivates a change in the internal structure of the organization—the creation of a System Division. The System Division leads the development and operation of the overall U.S. ground-based O/IR System, representing community interests in the integration of federally funded facilities (including NOAO, Gemini, and, in the future, LSST and GSMT) with resources from other U.S. astronomical facilities in order to provide a complete suite of capabilities for the U.S. community. The creation of this new division of NOAO, focused on System issues, will bring together all the programs that aim to strengthen or contribute to the System as a whole and are scientifically motivated or guided. This structure not only provides higher-level coordination to these programs, but also provides a context for initiating discussions that include the other divisions to identify those capabilities that are best developed and deployed within NOAO and those that are best left to other parts of the System. Thus, even NOAO's internal strategic planning takes on a System flavor. This division also becomes the home for broad discussions about the evolution of the System. This activity will be a critical aspect of understanding how NOAO maintains the balance between the current facilities and those of the future.

The System Division will include three of the existing NOAO programs: Major Instrumentation (to be renamed System Instrumentation), Data Products, and the GSMT Program Office. It will also include the Time Allocation activity. In addition, this division will have a new program, the System Development Office, which will lead the planning, design, and implementation of the specific tasks that make the System work. Its activities will include running TSIP and other System-wide programs through which capabilities are enhanced and access is provided, as well as convening discussions aimed at establishing community consensus about the evolution of the System and advocating these recommendations to groups that set policy or plan strategy.

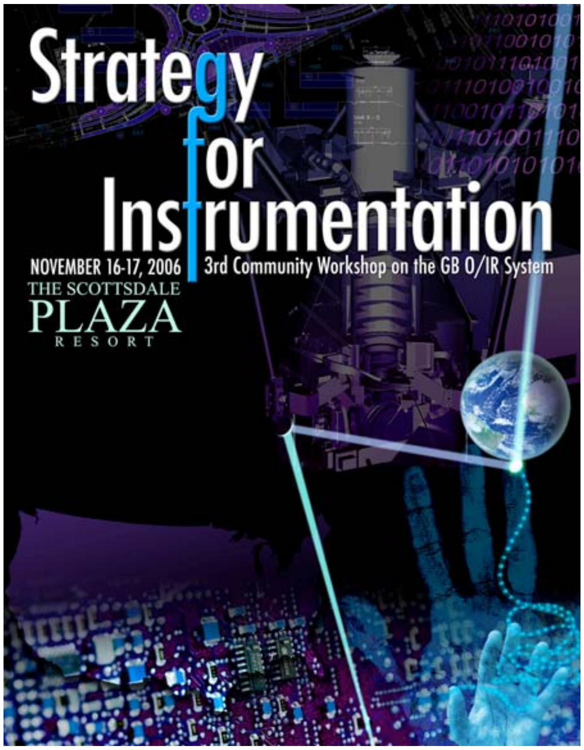
3.4.1 System Development Office

This new office has responsibility for leading the planning activity, both within NOAO and throughout the community, concerned with the status, efficient operation, and future evolution of the ground-based O/IR System. In addition, it will provide the effort needed to implement the System-wide activities and to provide an effective interface between the community and the committees and government offices that set policy or direction for the national astronomy program. Much of this work will be undertaken in collaboration with other groups within NOAO.

The planning activity has several components. First, this group will organize periodic, broad, community workshops on various aspects of the ground-based O/IR System, as has been done over the past seven years. Occasionally these will be aimed at establishing the overall status of the System and understanding general desires for new capabilities or programs, much as the three previous "System Workshops" have done. However, there is also a need for more focused discussions, in which the goal is to better understand a specific aspect of the System and its evolution, for example, "Supporting Capabilities for Large Surveys, Including the Time Domain," or "The System in the Era of GSMT," or "Community Needs for Optical Interferometry in the Next

Decade." In addition, this office will bring together specific groups to resolve more focused issues, such as the development of new programs to strengthen the System.

Much of the planning will be initiated by a standing committee that will integrate the discussions and reports of groups that look in depth at smaller pieces into a complete picture of the ground-based O/IR System. This committee will provide strategic vision that can come only from exploring the long-term evolution of the System and tactical advice on how to produce an optimized combination of available capabilities in the short term. This committee has been formed initially as an NOAO staff working group, involving staff from throughout the organization. External members will be added as the activity develops.



Strategy for Instrumentation: *The 3rd Community Workshop on the Ground Based O/IR System brought together 70 astronomers to discuss the evolution of the System. Illustration credit: P. Marenfeld NOAO/AURA/NSF*

The discussions described above will only have impact if they are communicated and advocated. A portion of that task will involve writing, distributing, and advertising reports of the workshops or white papers representing the outcome of the discussions. An additional activity will be to advocate these recommendations or resolutions, representing the community's interests both within NOAO and outside, to committees such as the CAA and the AAAC. The System Division will work closely with PAEO staff to ensure that a cohesive message about division activities and related new opportunities are communicated to the community in a variety of ways, from meeting exhibits to applications of the Web and new media.

Similarly, since the evolution of the System must be closely tied to the interests of the community, input from the community must be solicited, gathered, and analyzed or interpreted. NOAO will do this either by directly requesting input through surveys and polls, or by using standing or ad-hoc committees charged to gather and/or represent the community. One example of this is the ReSTAR (Renewing Small Telescopes for Astronomical Research) committee, established to provide a quantitative summary of the capabilities that the community desires on small and mid-size telescopes and how this is expected to evolve over the next ten years.

Over the five-year period of this agreement, the System Development Office will work to achieve an understanding or resolution of the following issues:

- What are the science-driven requirements for an effective system of smaller telescopes, and can a program be structured to create this System and provide community access to it?
- What is an appropriate balance between the support of existing research on telescopes of all apertures and the development of new, desirable capabilities?

- How should the suite of capabilities evolve to support new opportunities, e.g., discoveries of time-domain phenomena, or effective use of an Extremely Large Telescope?
- How can programs to develop new technologies, such as adaptive optics for Extremely Large Telescopes, be structured in order to incorporate strategic guidance?
- What is the scientific case for a large ground-based optical interferometric array, and what kind of program should be advocated to develop this technology?

3.4.2 Creating a System—TSIP and Beyond

TSIP, the Telescope System Instrumentation Program, has been a visible indication of the potential impact of the System perspective. Developed from a concept put forward in the last decadal survey, TSIP provides federal funding to independent (non-federally funded) observatories to build instruments or make other improvements and, in return, provides access to these facilities to the broad community. Alternatively, TSIP also provides a mechanism for institutions to sell telescope time to the community. TSIP allows proposals for improvements or access to telescopes of aperture 3 m and larger, though all but one of the subawards made since the program’s start in 2002 have been made to groups building instruments for telescopes of aperture 6.5 m and larger.

The annual TSIP proposal cycle consists of a solicitation distributed to the potential proposers, the assembling of an unconflicted panel to review the proposals, the negotiation of the subaward agreements and MOUs governing the telescope time with each successful proposer, and the monitoring and reporting of the status of the ongoing TSIP-funded instruments. The program has been routinely oversubscribed, and there is little reason to change its operation. It is clear that NOAO’s ability to carry out this program efficiently and in an unbiased manner has contributed to its success. The status of the program is reported every year to the NSF AST staff and to other interested groups such as ACCORD.

On the telescope time side, it has been necessary to develop mechanisms specific to each independent observatory for providing community access, since each observatory deals with time allocation, scheduling, user support, and observer interactions in a different way. Again, the flexibility that NOAO is able to bring to these negotiations has resulted in effective use of the time, as assessed by publication statistics. NOAO also tracks the user satisfaction with the time on independent telescopes through its Community Access Telescope Clearing House (CATCH) Web site, which also provides a simple way for researchers to find the capabilities that they need.

The main criticism of this program has been the inconsistency of the funding. After three years at $4 million per year, it dropped to $2 million per year for two years. In FY07 it returned to $4 million, and the President’s request for FY08 is $5 million. The consequence of this variation is that it makes it difficult for the independent observatories to maintain any kind of long-range plan for their instrumentation programs (at least to the extent that they rely upon TSIP), and it makes it difficult for NOAO to manage TSIP as a whole. The independent observatories have derived a number like $7 million per year as the level at which they would like to see TSIP maintained; this would balance their need for instrumentation funds against the number of nights on their facilities that they would be willing to make available.

While TSIP has been successful for the large telescopes, it has not resulted in the evolution of a System that is obviously responding to coherent strategic guidance, nor has it done much to develop a System that includes smaller telescopes. However, among the mid-sized (2- to 5-m) telescopes, there is real potential to develop a coherent System with significant new access for the community.

The reasons include: (1) these smaller telescopes are less oversubscribed and, therefore, less jealously guarded than the largest ones; (2) these telescopes are older, and resources for modernization would make them significantly more useful to their owners; (3) there exist a sufficient number of telescopes in this size class that one could implement a truly complementary suite of capabilities and make sufficient nights available to address the needs of the community for a reasonable amount of funding.

Consequently, NOAO has begun an aggressive program aimed at developing a true national system to provide access to small and mid-sized telescopes. Although it is early in this process, a path to a successful outcome is becoming clear.

1. A representative group of users of small and mid-sized telescopes has been organized and charged to assess and quantify the science-driven needs for capabilities met by telescopes of less than a 6-m aperture, using information gathered from the community. This is the ReSTAR committee, chaired by Dr. C. Pilachowski from Indiana University. In addition to quantitative descriptions of instrumentation, these capabilities will include estimates of the number of nights and telescope and site properties required. Various observing modes, queue, service, and remote, should also be specified when relevant, as well as the level of support needed to make such access effective. Their report is due by January 2008.

2. Several overtures to the owners and operators of mid-sized telescopes have been made, in order to begin understanding their interests so that NOAO can design a program that will be appealing to them. Such a program might include funding to support their operations, the modernization of their facilities, and the development of new capabilities. In exchange, they would be expected to provide nights to the community in a uniform and unified way—perhaps through the NOAO TAC process. While information has been gathered from all non-federally-funded facilities, NOAO has initiated more extensive discussions with two groups that are developing new telescopes: Lowell Observatory, which is building a 4.2-m telescope, the Discovery Channel Telescope, in northern Arizona; and the Las Cumbres Observatory Global Telescope Network, a world-wide array of 1.0- and 2.0-m telescopes designed to follow up time domain discoveries.

3. As the ReSTAR discussions conclude, NOAO will develop a detailed plan to provide the capabilities needed. This plan may include several different approaches, including new instruments or observing modes for NOAO telescopes, agreements with non-federally-funded observatories to provide telescope time in exchange for resources, or proposals to develop and build new facilities. Depending on the resources available, NOAO will then implement this plan.

3.4.3 GSMT Program Office

Background

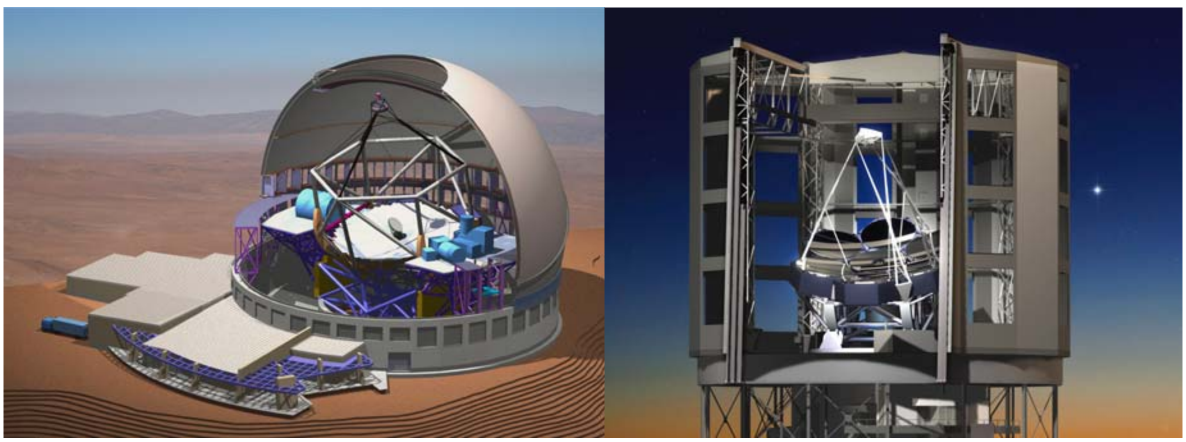
In May 2000, the Astronomy and Astrophysics Survey Committee recommended, as its highest priority, large, ground-based initiative, the technology development for a 30-m aperture Giant Segmented Mirror Telescope (GSMT), with the intent of beginning construction within the decade. The AURA New Initiatives Office (NIO) was formally established in January 2001 to work towards this goal. Less than a decade from now, astronomers will have access to major new tools on the ground (ALMA) and in space (JWST). To exploit these tools fully will require a new generation optical/infrared telescope with appropriate sensitivity and resolution capabilities.

Beginning in 2003, NIO and the CELT Development Corporation began to work together on a GSMT design and development effort. Resources for this effort came from AURA (NOAO and

Gemini) staff, and from funding through a proposal submitted to the NSF on June 30, 2004, "Enabling a Giant Segmented Mirror Telescope (GSMT) for the U.S. Astronomical Community."

This proposal requested $39.4M to provide funding for Giant Segmented Mirror Telescope development and was to provide support for the Thirty Meter Telescope (TMT) design and development phase; for a second extremely large telescope (ELT) concept; and for related technology and instrument development efforts, public outreach, and a theory challenge program. GMT was subsequently chosen as the second ELT concept by a competitive review. Some funding, totaling approximately $3M, has been provided under this proposal in fiscal years 2005 and 2006, with additional funds anticipated in fiscal years 2007 and 2008, possibly totaling $10M.

In 2006, the Senior Review significantly changed the course of this NOAO activity. The Senior Review recognized that (a) the NSF would not be able to come up with funds to assist with construction on a timescale interesting to either of the two projects, and (b) the existence of two independent projects made NOAO's collaboration with one of the two problematic. Accordingly, it was recommended that NOAO efforts be redirected to focus on leadership and planning, rather than



During the next decade, one or more "extremely large telescopes"—telescopes with a collecting area equivalent to a primary mirror diameter greater than 20 meters—will be built. NOAO is working to provide ELT access to the U.S. astronomical community. Two ELT concepts to whose developments NOAO and the NSF have provided support, are the Thirty Meter Telescope (left) and the Giant Magellan Telescope (right). Illustrations courtesy of TMT and GMT, respectively.

engaging in direct participation in one project at this early stage. This role will be carried out under the renewed cooperative agreement by the GSMT Program Office as an entity integrated into the NOAO System Division, rather than as a separate AURA entity. The details of this role are outlined below.

GSMT Program Office Mission

The GSMT Program Office (GSMTPO) will promote the development of both TMT and GMT at a pace that recognizes the timescales of both federal and private budget processes. It is currently restructuring its existing relationships with GMT and TMT, withdrawing from direct partnership, addressing any previous support imbalances, and establishing symmetric interfaces with both projects.

As a result of discussions involving AURA/NOAO, TMT, and GMT, NSF has asked that NOAO act as NSF's "Program Manager" for the GSMT technology development effort at a national level. In this role, NSF expects that AURA/NOAO will do the following:

- As recommended by the Senior Review, promote the development of both TMT and GMT at a pace that recognizes the timescales of the MREFC and federal budget processes. At present, both projects believe that they can secure non-federal construction funding on a faster timescale, so that eventual NSF support would most likely come in the form of contributions to operations and supplemental funding, such as additional instrumentation or other facility enhancements.
- Understand and champion the national needs for a GSMT in any public/private partnership. This requires:
    - establishing and running a national community Science Working Group;
    - establishing and maintaining the national Design Reference Mission (DRM) to set scientific performance expectations for candidate designs;
    - providing an independent evaluation of the community operational needs, costs, and scientific sociology of a GSMT, then leading the community in understanding the implications of these for both a GSMT and the necessary underlying instrumental and human resource capability; and
    - providing the results of these studies in a timely fashion as input to the next decadal survey. The NSF considers that a re-affirmation of the GSMT priority is a necessary condition for commitment of construction or operations funding.
- Advise NSF about engineering design performance necessary to respond to the DRM and the technical progress of both projects; this should not be interpreted as NOAO holding independent reviews of either project.
- Assure a healthy scientific enterprise in the GSMT era. In this regard, NOAO should lead in defining the System, being certain that it addresses an appropriate range of apertures, suite of instrumentation, and utilization of existing non-federal facilities where available. NOAO must assure that this System is robust against the delays and uncertainty in the path to an eventual GSMT.
- Communicate with the entire community about the status of the GSMT projects, their evolving scientific priorities, and new opportunities for involvement and participation.

The resources to carry out these activities will draw on the community as a whole, primarily through the SWG and the activities that it sponsors, and will make use of the expertise of NOAO staff, as well as other AURA staff engaged in the development or operation of major facilities such as LSST, ATST, and Gemini. The ability to draw on this pool of expertise within AURA-managed institutions is critical, since it provides access to a broad range of skills and experience without the need to support a massive full-time staff. Furthermore, by drawing on staff engaged in projects of comparable scope, GSMTPO will be able to make use of the knowledge and insights developed during the course of these projects. As a result, the GSMTPO core staff—personnel dedicated exclusively to GSMT activities—is expected to be very small for the initial phase of the cooperative agreement. Their primary role will be to coordinate the larger pool of expertise and to provide continuity over time and across activities.

As indicated in the staffing sections, the effort associated with GSMTPO starts at approximately 9 FTE, increasing to approximately 11, but draws on the collected expertise of between 25 and 30 individuals. These figures do not include those technology development or GSMT instrument design and construction efforts managed by System Instrumentation and funded outside the regular NOAO budget.

In the longer term, there will be additional efforts:

- Identifying areas of commonality or overlap in technology with a view towards optimizing federal and non-federal budgetary commitments.
- Carrying out any appropriate independent technology efforts of importance to both programs and, ideally, to the O/IR community as a whole, subject to available funding.
- Participating in development of instruments, adaptive optics systems, and similar projects intended for use on ELTs to which the community has access.
- Planning for the interfaces for community access, potentially including queue scheduling, as well as archiving and archive access.
- Assisting NSF in defining and realizing possible alternatives to a competitive down-select between TMT and GMT.
- Advising NSF on options for international collaboration at a governmental level.
- Representing the NSF and the national community in any eventual partnership that operates the GSMT.
- Coordinating and developing of effective public outreach and education programs related to the science and engineering of extremely large telescopes. Two pilot outreach efforts supported by AURA GSMT funds are under development at NOAO now.

Both GMT and TMT currently expect to initiate construction during the period of the renewed cooperative agreement, though neither will have begun the hand-over to operations by the end of the period. The schedule for the European ELT is less well defined at present, although it is likely to be similar, though somewhat later. As a consequence, technology development of common interest applicable to the telescopes themselves must be initiated early in the cooperative agreement—almost certainly no later than fiscal year 2009. There is a greater “window of opportunity” for technology development efforts related to instruments and adaptive optics; as these are also areas where there is greatest synergy with other facilities, it may turn out that this is where NOAO’s effort is concentrated.

Technology development efforts are most likely to take the form of partnerships, either with industry or universities, or both. For this reason, they will not, for the most part, require a large staff within NOAO, though the ability to make significant capital commitments is essential. The funding for these efforts will not be possible within the NOAO base budget, though the coordinating staff may well be included. The identification of suitable development programs must be a cooperative effort involving NOAO, the active ELT projects, and, potentially, representatives of other major observatories. Examples of such programs might include detector development, array controller development, and durable coating development.

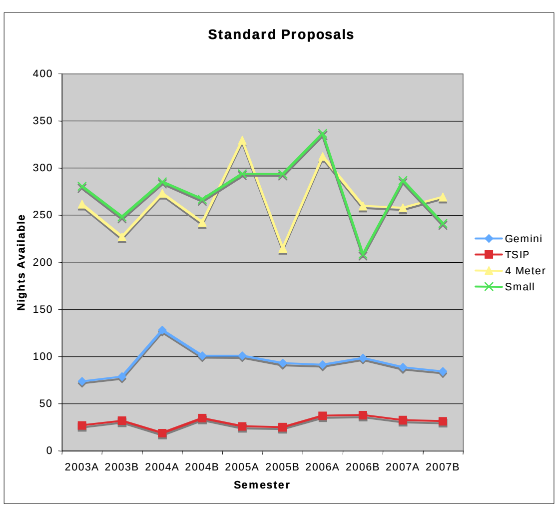
Participation by NOAO in the design and construction of instruments or adaptive optics systems is likely to be led by the System Instrumentation Program, although the senior technical and scientific staff involved may be many of the same individuals who are engaged in supporting GSMTPO activities. This ability to share resources between programs is, as noted above, critical to maximizing the efficient use of highly skilled staff.

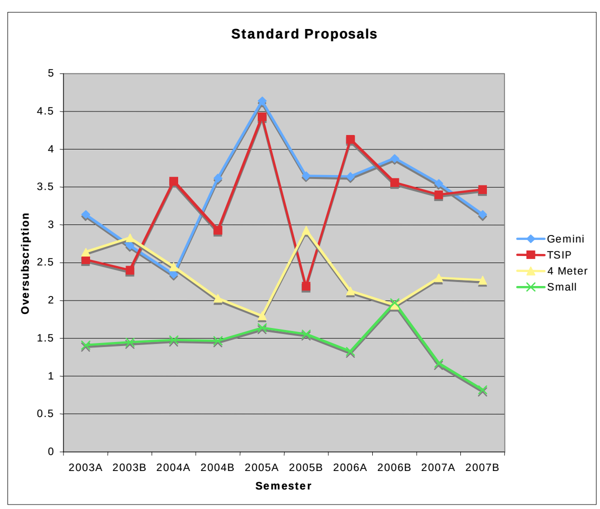
The end of the renewal period coincides with the point when the NSF should be able to make a firm commitment to fund operations or facility enhancements. Therefore, it is important to use the period after the completion of the decadal survey to develop the means for providing access to one or more of the facilities then under construction; the objective should be to ensure that the U.S. community has the access it desires as soon as the facilities enter scientific operation. The planning staff and procedures will be similar to those used to develop input for the decadal survey—a combination of activities tied to the GSMT SWG and expertise drawn from AURA staff. The effort to define interfaces will be able to draw on the experience developed over the course of the preceding decade within the National Gemini Science Center and the Data Products division.

As the cooperative agreement period nears its end, it will be necessary to start building up the infrastructure required to actually support community GSMT access and publicity for the results that it will produce, although the period of regular operations will not start until well after the end of the period covered by this proposal. However, the likely demands of the GSMT era dictate the importance of starting a renewal of the senior staff in the latter part of the proposal period by means of a small number of more junior hires who can develop the needed expertise during the final construction/early operations phase of the GSMT project(s). By that time, it should be clear whether a separate GSMT science center is desirable, or whether it would be better to merge Gemini and GSMT access into a single function.

3.4.4 Telescope Time Allocation

With the evolution of Gemini to a mature, operating observatory and the increased availability of time on non-federally funded telescopes through TSIP, the stress on the proposal processing and evaluation system has increased. Typically, more than 400 proposals are received every semester for time on 17 different telescopes; some proposals request time on more than one telescope. The number of proposals will rise as SOAR completes its commissioning and with the development of a new System of mid-sized and small telescopes. The following two figures show the 5-year evolution of nights available and oversubscription rate (standard proposals only), categorized by telescope size (the TSIP category includes the time given out on 6.5- to 10-m private telescopes).





The mechanisms in place to support the proposal submission and evaluation process have evolved slowly and with careful thought and planning. Proposals may be prepared using a Web-based form or on a LaTeX template. The submitted proposals are categorized by subject area, and divided among panels that are broadly discipline-based: galactic, extragalactic, and solar system. As the number of proposals varies, the number of panels can be changed with little impact on the process itself. After panel review of all the proposals is complete, a merging committee comprising representatives of each panel meets to produce merged, ranked lists for each telescope. This process is well supported by software tools, and statistical information about the proposals and approved programs are easily available to support investigations of the effectiveness of the process. No dramatic change is foreseen for the time allocation process as it expands to address a more complex suite of capabilities for the entire ground-based O/IR System.

The allocation of telescope time also addresses strategic issues. In 1999, following a community-based workshop that recommended the facilitation of survey projects as the single most important way that NOAO could support observations on large telescopes, the NOAO Survey Program was initiated. Up to 20% of the time on NOAO telescopes is given annually to large projects that require multi-year commitments and promise to deliver coherent datasets to the community through the NOAO Science Archive. This program has been consistently highly oversubscribed, and these survey projects have provided some of the highest-impact publications from NOAO facilities.

NOAO also makes small amounts of time available for successful proposers to HST, Spitzer, and Chandra. These proposals are peer-reviewed through the allocation processes of these NASA missions, and time is granted on ground-based NOAO telescopes if it is needed to achieve the proposed goals of the project. The relative amounts of time and capabilities made available through these programs are reviewed and adjusted periodically through discussions involving groups such as the NOAO Users' Committee and the AURA Observatory Council.

Finally, it should be noted that the proposals received from the community are the most direct statement about the capabilities that NOAO makes available. Certainly, understanding the relationships and evolution of the oversubscription rates for different telescopes and different instruments provides important input to an understanding of what the community wants.

3.4.5 System Instrumentation Program

As an effort within the System Division, the System Instrumentation Program will lead efforts to define the new instruments required for an effective national System of telescopes. These discussions will broadly cover instrument capabilities needed on telescopes of all apertures, but in ways that are appropriate to the different needs of different size classes. Their respective observatories generally define instrument programs for large telescopes, and the System Instrumentation Program will continue to collaborate on proposals and construction programs for instruments for Gemini and other large telescopes as opportunities permit. System Instrumentation (SI) will also focus on identifying and, where appropriate, supporting the development of new instruments that may be needed within the ensemble of medium and small telescopes (discussed above) as those telescopes begin to participate in a national System.

In addition, SI will carry on a modest program of technology development, primarily in the areas of detector testing and controller development. This effort will have two goals: to ensure that all telescopes in the System have support for and access to appropriate and affordable new technology so that they can maintain their efficiency and scientific power, and to help ensure that new technologies needed to enable a U.S. GSMT are available when needed.

Development of new capabilities within a national System

NOAO anticipates that the development of a national System of mid-sized telescopes will include some component of new instrument development for the participating telescopes. NOAO's plan for this System development begins with the ReSTAR committee, which has been tasked with identifying needed new capabilities, some of which will require new instruments. NOAO's SI group will provide the scientific and technical expertise to turn these identified needs into specific instrument concepts with enough detail and support to enable reasonable cost estimates and lay out cost vs. performance trade-offs for consideration by the user representatives.

When those guiding the development of this System decide that a particular new instrument is worth pursuing, the SI group will work with the community to identify suitable partners for the detailed design and construction of the instrument. The natural partners for such efforts would be the university instrumentation groups or other observatories that are participating in the national System, but partners can also be drawn from other institutions that have some special expertise needed for the particular instrument. The SI group's role here would be to find and facilitate the formation of the optimal partnership for a given project, which may or may not include the group itself. When the SI group can provide necessary strengths or resources to a partnership, it would naturally play a role in the construction effort, but such participation would be determined on a project-by-project basis.

Instrument needs of large (6.5 to 10 meters aperture) telescopes are defined by the operating observatory, as are the means of selecting instruments and construction teams and the terms of participation. NOAO previously has been an active bidder for Gemini instrument projects and expects to continue bidding to the extent consistent with the scientific interests of NOAO's instrument scientists, availability of needed staff support, and other programmatic constraints. In addition, NOAO is open to participation in mutually beneficial collaborations to construct instruments for other large telescopes.

Collage showing the evolution of the wide-field IR imager NEWFIRM from idea through design, fabrication (optical, mechanical, and electronic), and installation, to scientific observation.

When the SI group does participate in a project, it will draw skills and resources from other NOAO groups as needed to provide the higher level of effort that is required for an instrument construction project. Because NOAO does not expect that there will always be a steady flow of instrument construction work, it makes more sense to plan on staffing up when such a project is coming, rather than maintaining the full complement of required skills within the group at all times. Such staffing up would preferentially be done by engaging people from other NOAO divisions whenever possible, but it would be supplemented as needed by new hires for the duration of a given project.

Whenever an instrument is under construction for the System, the SI group would also provide whatever level of project oversight and reporting is appropriate for the construction partnership based on funding source and level of connection to the national System. When the SI group is a partner in the project, this oversight role would include acting as project reporter, collecting periodic progress information from the project manager (who could well be within the SI group itself) along with technical reports from all partners' engineering teams, and reporting the status to the committee responsible for System administration as well as to the NSF. When an instrument is under construction with System development funding by a partnership that does not directly include NOAO's SI group, the group would still have a responsibility to oversee the project at a level necessary to assure the NSF that the funding is being applied responsibly. This oversight role would involve taking part in formal technical reviews and monitoring progress through less formal quarterly progress reviews and reports. In either situation, the oversight and reporting would be carried out with an eye towards verifying that the project team is meeting schedule and budget restrictions, making good progress on technical challenges, and is ultimately able to deliver the new capability that the System needs.

To carry out this role of facilitating instrument partnerships, the SI group would need a core staff of a small number of scientists, equivalent to the functional time of two or three people, who were broadly experienced instrumentalists and observers. These scientists would be supported as appropriate by effort from one or two senior optical and mechanical engineers and part of the time of an experienced project manager. Clearly, the level of effort for both scientific and engineering staff would vary depending on the current level of instrumentation activity and interest within the national System. During times when the only activities are reporting to various committees and participating in informal discussions of possible future instruments, the level of effort could be as low as 0.5–1.0 FTE of scientist time with only a small amount of engineering support. During times when a specific instrument concept is being fleshed out to an initial design, the level of effort to be supported by the SI group base budget could be as high as 2–3 FTE of scientist time and 1.5–2.0 FTE of engineer time. During times when an instrument is under detailed design and construction and the SI group is an active partner, the level of effort would be considerably higher, but the additional effort would be supported by the System development funds external to the SI group's base budget.

Technology development for the System

The other way in which NOAO's SI group can support an effective national System of telescopes at all apertures is through sponsorship of a program to develop new technologies for astronomy. For a modest ongoing investment, the SI group could help the entire U.S. astronomical community by promoting the development of improved detectors and controllers, or by stimulating needed developments in optical coatings, just to name two generic examples. These expenditures would benefit the national System by supporting ongoing efforts to keep the KPNO and CTIO telescopes current with the evolving state of the art, as well as provide similar access to the latest technologies to other telescopes of all apertures participating in a national System. Further, these expenditures could also be of significant benefit to the efforts of the GSMT Program Office by helping to ensure that critical enabling technologies are available when needed. Housing this technology development within NOAO's new System Division provides the maximum possible input and involvement from all parts of a national System in decisions about which technologies to pursue and how best to invest the limited resources available.

This effort would begin by building on existing NOAO programs in detector testing and development of new image acquisition systems. The WIYN-ODI and Dark Energy Camera projects both intend to use NOAO's MONSOON image acquisition system, but both also require developments beyond the existing MONSOON capabilities to meet their specific needs. NOAO's new SI group will continue to work in close collaboration with people and institutions in both projects to ensure that these major new capabilities become part of the national System. In addition, the CTIO and KPNO directors have identified new, state-of-the-art, detector controllers as key early elements of their observatories' modernization programs. MONSOON offers many advantages to them, but again it requires some additional developments, different from those needed by the large-format imager projects, to be optimized to the goal of replacing outdated current systems. These developments may well be of interest to other telescopes, including 8- to 10-meter class facilities, that currently use a wide variety of controllers some of which are obsolete or otherwise difficult to maintain.

Beyond the MONSOON work, there are significant opportunities to partner with other institutions or private industry in raising the capabilities and lowering the costs of critical technologies. Examples include: working with companies and institutions with expertise in optical coatings to develop more efficient coatings that can be applied with the needed quality over very large areas, to yield the large filters and dichroics that will be needed by future telescopes and instruments; working with detector companies to implement and perfect new ways of controlling infrared and optical arrays that incorporate some control logic on the detector itself; and working with detector makers to devise ways to lower the cost per pixel of infrared arrays, which will be needed in large quantities by instruments and telescopes being planned now. In all these cases, the program would require both labor and cash. The labor would take the form of scientist time to define and guide the project and engineer time as needed to help carry it out, and the cash would take the form of a matching contribution to a hypothetical industrial partner to leverage against the partner's own contribution. Again, this type of activity is best housed within the overall System Division to ensure the maximum benefit to the overall astronomical community and to telescopes of all apertures.

Carrying out the early phases of this technology development program will require only modest scientist time, at a level of about 0.3–0.5 FTE/year. This time will be devoted to providing guidance and scientific oversight to the program of completing developments in the MONSOON systems. The engineering effort during this period will be somewhat larger, including 3–4 FTE/year of electronics and software engineers, about 3 FTE/year of skilled electronics technicians, and up to 1 FTE/year from an engineering manager. This effort will ramp down considerably as ODI and DECam come on line, and as the KPNO and CTIO controllers are replaced. In the later two to three years of the cooperative agreement, the balance of effort in technology development will shift away from engineers and technicians and towards scientists, whose time will be needed to define the developments needed, conduct the specific experiments and planning exercises that are NOAO's part of a development partnership, and establish the appropriate relations with scientists and managers at other institutions and in industry to set up the necessary partnerships. Although much harder to predict, the effort levels in these later years are expected to be 1–2 FTE/year of scientist time, with engineering and technician support fluctuating between 1 and 3 FTE/year depending on projects undertaken.

3.4.6 Data Management and Science Support for the System

Motivation

On any given night, more than a trillion bits of astronomical data flow from instruments on U.S. ground-based O/IR telescopes. In most cases, these bits are of greatest interest to the astronomers at the telescopes making the observations, but the scientific potential of these bits does not stop with those astronomers and their focused observational programs. Those same images and spectra can be of great value for other astronomers pursuing different research programs. In order to realize the full scientific potential of the data taken each night throughout the System, a coordinated program of data management must be developed to capture, archive, and deliver these data to the wide community of potential users.

Data management for the System, including archives of data obtained from the observatories and instruments that make up the System and the scientific support necessary to enable effective use of the archived data, has a multiplicative potential to enhance the efficiency of the System as a whole. Capturing raw data and delivering it in a uniform manner to PIs and CoIs represents a gain of efficiency System-wide. Automatically processing data provides a direct efficiency gain for users, since they start with at least modestly processed data instead of raw data. In addition, archives provide the opportunity for reuse of the data by other astronomers, leading to efficiency gains of factors of two or more when data is reused. Also, when instrument scientists can characterize a problem (or even discover an anomaly before it becomes a problem) by using the output of automated processing or simply being able to look at historical images, their activities are more efficient. Sometimes it is even the users themselves who can identify issues with the instrumentation by having access to the historical images! Finally, keeping track of images taken and encouraging PIs to check the archive before proposing to use System resources leads to a more efficient use of future telescope time by decreasing the duplication of observations.

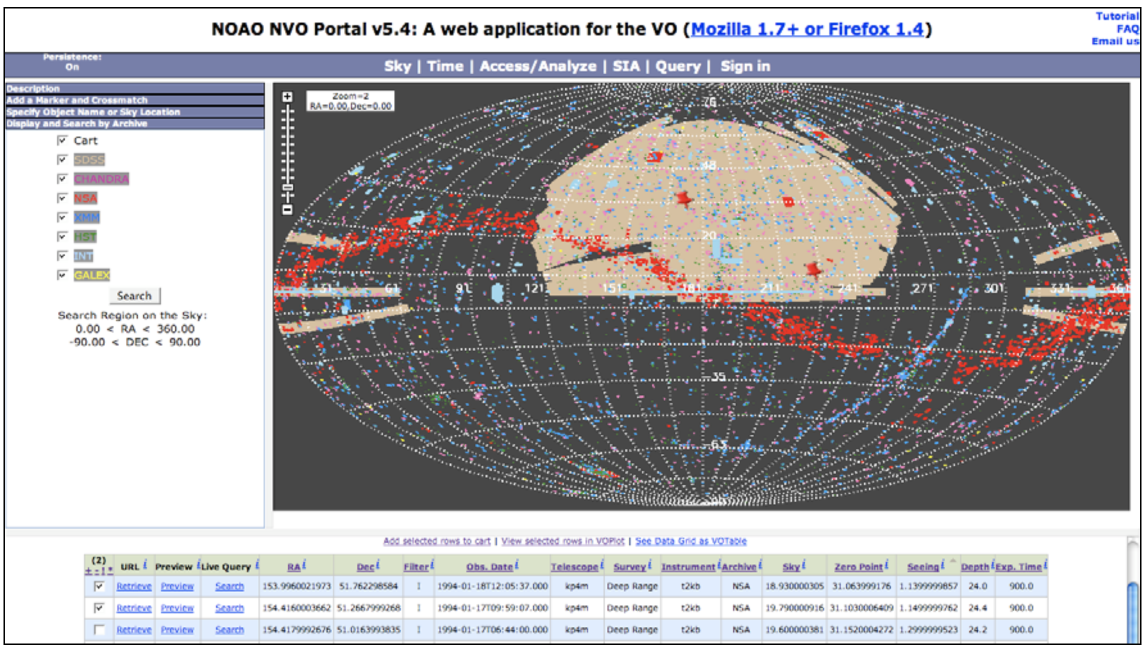
NASA and its space-based facilities recognized the value of archival holdings early on. For all of its missions, NASA has invested significantly not only in the infrastructure necessary to capture, process, archive, and deliver the data to users (partially out of the necessity of space-based facilities), but also in the scientific support for use of the archival data products. Over the past two decades, ground-based astronomical facilities (led by ESO) have begun to invest in effective data management in order to realize the advantages in efficiency and scientific productivity. Surveys have been the focus of much of the ground-based effort to date, and the outstanding success of the Two Micron All Sky Survey and Sloan Digital Sky Survey in multiplying the scientific impact of their observations through public access to the datasets has clearly established the effectiveness of archival holdings from ground-based facilities.

The NVO as a new NSF facility—an important component of the System

The scientific potential of archival astronomy and the promise of linking all major astronomical data assets into an integrated system was recognized and highlighted in the most recent decadal survey. The committee's highest priority small project was the creation of the National Virtual Observatory (NVO), charged with creating standards and analysis services based upon those standards to enable data discovery and analysis across the broad spectrum (in wavelength as well as in type) of astronomical archives. The NSF has moved forward on this recommendation, funding the development of the NVO over the past five years. In coordination with NASA, the NSF is now on the verge of establishing the NVO as a significant new U.S. astronomical facility, similar in some ways to the other facilities recommended in the decadal survey, such as LSST and GSMT.

However, the design of the NVO is of limited scope. The NVO will not be a traditional "brick and mortar" astronomical facility. First and foremost, it will establish and evolve the standards and interfaces that are to be used in linking archives and their data holdings together into a seemingly uniform resource. Its charge also includes the coordination of activities at the archive centers in support of the NVO facility goals and activities, including user support, system verification (testing), and system maintenance (monitoring the distributed system). Finally, the NVO must also lead the development of unifying tools and services that take advantage of the combination of datasets from the wide variety of distributed archives using the standards and interfaces NVO manages.

The fundamental limitation of the NVO's scope is that it must be built upon a robust and reliable set of astronomical archives. The NVO will not provide *content*, the actual data that will be used in the scientific research. It must rely upon a distributed network of content providers, specifically the archive centers of astronomical observatories at which the data is collected. Those archive centers are responsible for providing the effort and resources necessary to manage the data, archive it, and make it available through the NVO. Being closest to their specific communities, the centers also must be responsible for leading their communities in the use of the NVO, supporting the development of tools and services that enable effective scientific use of the diverse datasets, while also providing scientific support specific to the datasets they host.



NOAO-Sky is a portal to data and tools through NVO-compliant interfaces. It presents a graphical view of the sky on which a researcher can identify interesting datasets, download them, and analyze or process them.

While specific ground-based O/IR surveys, such as 2MASS and SDSS, have well-funded and effective archival efforts, data management for the entire System is still lacking. NOAO must provide the fundamental data management infrastructure and archive/NVO scientific support for the System as part of its leadership role. In doing so, NOAO will become one of the principal components of the NVO, both in data volume and in the broad range of science which will be enabled by the data products hosted in NOAO's ground-based O/IR archives.

NOAO has been involved with planning for the education and public outreach aspects of the NVO for the past five years, and anticipates an ongoing role in this effort. Specific ideas proposed to the NVO proposal team include a new Web-based interface for image processing in classroom environments and development of virtual educational “ambassadors” who can lead educators and the public into relevant activities and train them to explore on their own.

NOAO’s System data management plan & the Data Products Program

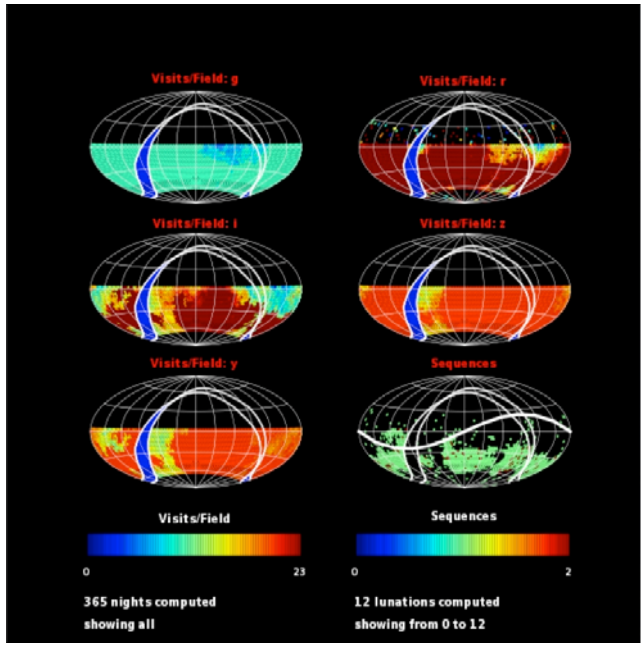
Data management and archival scientific support for the System consists of three core activities: capturing content, providing access to the content through standard (i.e., VO) interfaces, and providing effective user interfaces with integrated tools and services to support the scientific exploration and use of the content. The fundamental part of System data management is establishing procedures and infrastructure that allows us to capture the data, preferably just as they flow out of the instruments at the wide variety of telescopes to be supported. This distributed infrastructure must transport and safely store the data, with multiple copies in multiple locations to ensure their long-term availability. Once the content is captured, a well-managed access system must provide interfaces that serve a wide variety of users: the PIs accessing their proprietary datasets, instrument scientists accessing data to evaluate instrument performance, and the astronomical community after the proprietary period has elapsed. In the era of VO standards and protocols, providing access can be broken down into (a) the implementation of machine (VO protocol) interfaces, which might be considered the VO back-end; and (b) user interfaces, the VO front-end, that are coupled with the tools and services that serve the needs of the particular user. The Data Products Program (DPP) will serve as the focal point of NOAO’s efforts to develop and operate this necessary data management and scientific support infrastructure for the U.S. ground-based O/IR System.

Given the complexity of the System, with multiple organizations distributed widely over much of the western hemisphere, the DPP will initially focus its developmental and operational data management efforts on the NOAO core and closely affiliated facilities at the two principal sites, CTIO and KPNO. Given that, by sheer numbers, NOAO operates or supports more instruments than any other single organization in the System, the NOAO Science Archive (NSA) will rapidly become not only the single largest content resource of the NVO in data volume (with the CCD Mosaic Imager and NEWFIRM datasets dominating that volume), but also will be the most heterogeneous content resource, providing a broad range of scientific potential through its holdings.

This initial effort focused at CTIO and KPNO will be an integral part of the renewal of infrastructure and modernization of these observatories, which was called out in the Senior Review. The data management efforts will provide gains in both the efficiency and effectiveness of these observatories by supporting observers at the telescope with rapid feedback regarding data quality (at least in the cases of the CCD Mosaic Imager and NEWFIRM), supporting PIs accessing their proprietary data, and supporting instrument scientists in their monitoring of instrumental performance, in turn enabling better user support. These efforts also represent a fundamental modernization of these core System facilities, offering the new capability of archival access to the data from the telescopes at CTIO and KPNO, access that is integrated into the newly established NVO facility.

Even this initial work will benefit not only users of NOAO facilities, but also users of all of the System facilities, given that everyone will have access to the wealth of data produced at the NOAO and affiliated telescopes. However, the goal of NOAO is to provide leadership in System-wide data management. As the data management infrastructure is proven at the NOAO sites, both through evolution of the infrastructure itself and through the establishment of effective operational procedures, the development efforts will turn toward expanding the infrastructure to support data management for the broad suite of telescopes and instruments that make up the System. Those efforts will be complemented by leadership in the development of data management for the next generation of instruments System-wide, including those coming to NOAO telescopes (e.g., DECam and ODI). These broader initiatives will be undertaken as *collaborations* with the providers, be they instrument builders or observatories providing nights on specific telescopes. In particular, DPP will work with instrument builders to ensure that data management is an integrated part of the design and development of the instrument, so that the delivered instruments can feed data (usually both raw *and* reduced) into the System's data management infrastructure and hence into the NVO. This collaboration is especially important for the new large-format optical and IR imagers that will appear on telescopes throughout the System during this cooperative agreement, given both the large data volumes and the vast scientific potential the archived images from these instruments will represent.

Responsibility for helping the community to realize the full scientific potential of the data from ground-based O/IR telescopes extends all the way to tools for data reduction and scientific analysis, or, more generally, "science support software." NOAO will continue to develop such science support software, building on the strong heritage of IRAF. NOAO anticipates this activity to evolve significantly over the period of this proposal, initially from continued (albeit limited) support of IRAF, moving to participation in the development or evolution of the next generation of science support software, developed in collaboration with other astronomical facilities (such as STScI, Gemini, CfA, etc.) and the community. This evolution will be strongly influenced by the ongoing development of the NVO, and eventually should blur the difference between desktop and Web-based scientific tools and services.



Results from a trial run of the LSST observing simulator, which takes into account observing constraints such as object availability, lunation cycles, weather interruptions, etc., and charts a course for efficient observing given constraints from the science programs of interest. The results are shown here on Aitoff projections of the sky for a test run of 1 year's worth of observing in 5 filters, using a possible set of desired science programs. The first 5 plots show the number of repeat visits for each of 5 filters as distributed by location in the sky. The final plot shows the number of times an observing "sequence" needed to identify NEOs was completed in any position of the sky for that year. The simulator is being continually improved as better models of the telescope system become available, and as the science cases become clearer. The results feed back into better designs for both the telescope and system, as well as for designing the observation strategies for LSST.

3.5 Large Synoptic Survey Telescope

The Large Synoptic Survey Telescope (LSST) is a large-aperture, wide field-of-view, ground-based, optical imaging telescope that will survey the entire available sky every few nights in 6-wavelength bands. The range, depth, and speed of the survey will produce a database suitable for addressing with the *same* data set a wide range of questions in solar system science, astrophysics, cosmology, and fundamental physics.

Specific investigations will not be allocated time on the LSST, but rather it will conduct a ten-year survey that will produce a single universal set of observations that will feed all scientific investigations in parallel. The 30 terabytes of data generated nightly will be processed in real time to generate alerts for interesting transient events. Catalogs and archived data will be publicly available without a proprietary period. The data management system, which is an integral part of the project, is designed to serve data to individuals who have simple queries as well as to computationally intensive investigations that utilize the entire data set. A public outreach effort is planned that will make the survey and its movie-like imagery of the sky available to teachers, students, and the interested public.

A large-aperture survey facility was identified in the most recent decadal survey for astronomy and astrophysics as a scientific priority and has been consistently endorsed by other National Research Council reports[1] over the last several years. A community-based Science Working Group (SWG), chaired by Michael Strauss and commissioned and supported by NOAO, amplified these reports into a detailed design reference mission for a large-area survey instrument (*www.noao.edu/lsst/DRM.pdf*). Simulations have demonstrated that the scientific goals endorsed by these studies can be achieved with the observing strategy adopted for the LSST.

3.5.1 NOAO and LSST

The LSST project will be carried out by the LSST Corporation (LSSTC), which was established as a non-profit 501(c)3 corporation in the state of Arizona by NOAO, the Research Corporation, the University of Arizona, and the University of Washington. Membership in the project has grown to 20 institutions, including universities, DOE laboratories, and private organizations. LSST has already received millions of dollars of direct support from private sponsors and has been awarded a four-year NSF Design and Development contract[2] of $14.2M. The total construction and commissioning cost of the project has been established at $389.6M. LSSTC submitted a construction proposal to the NSF Major Research Equipment and Facility Construction (MREFC) program in February 2007. This proposal requested $241.6M of the total from NSF, with the remainder to be provided by the DOE ($96.3M) and non-government sources ($51.7M)[3]. The proposal requested an MREFC new start in FY10, which would allow the survey to begin in October 2015.

Location of the chosen site for the LSST, in relation to Pachón and its telescopes.

NOAO has provided continuous support to the LSST project since its inception, beginning with a joint presentation with the University of Arizona to the O/IR panel of the most recent

[1] National Academy of Sciences/National Research Council Reports:
 a) Astronomy and Astrophysics in the New Millennium (2001)
 b) New Frontiers in Solar System Exploration (2003)
 c) Connecting Quarks with the Cosmos: Eleven Science Questions for the New Century (2003)

[2] LSST Design and Development: SPO 9

[3] $389.6M is total project cost in FY06 dollars with 29% contingency. The sum of the inflated yearly cost (“then year”) is $467.1M with contingency.

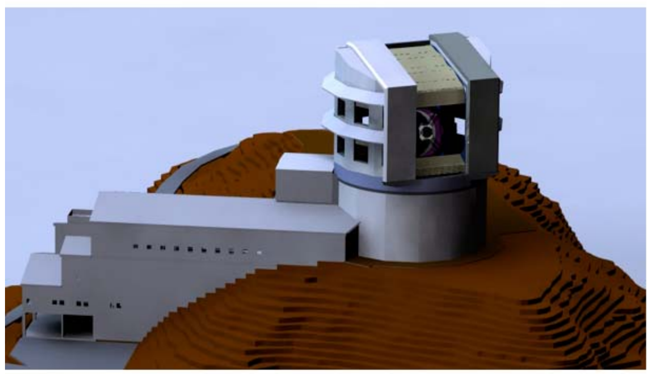
astronomy and astrophysics decadal survey. Starting with early development of the scientific case and working with partners to establish design concepts, NOAO has provided critical scientific, technical, and programmatic support to the project. LSST will be sited on AURA property on Cerro Pachón, close to Gemini and SOAR. According to the plan presented in the MREFC proposal, NOAO will be responsible for site development and for construction of the telescope and supporting facilities in Chile. The majority of NOAO's resources are currently focused on the design of these facilities. Support from the NOAO operations budget is being supplemented with some of the funding from the NSF D&D grant.

NOAO played a lead role in establishing the current corporate and project structure and is active in the governance of the project, which is the responsibility of the LSST Board. NOAO scientific staff are active in defining the science requirements for the project, developing the operations simulator, and engaging community participation. PAEO staff have ongoing roles in preparing LSST promotional materials and press releases, and are engaged in a prototype, LSST-oriented, middle-school-level research project on the characterization of near-Earth objects.

3.5.2 NOAO's LSST Program

From FY09–13, the NOAO program for LSST will focus on these objectives:

1. Support the LSST Design and Development phase, primarily the telescope and site group hosted at NOAO, at the levels committed to in the NSF-approved D&D proposal. The critical path for the project goes through several work packages assigned to NOAO: the mirror cell, the telescope enclosure, and the telescope mount. In order to meet the current LSST schedule, the NOAO work on these major subsystems must proceed at a pace that will allow contracts to be let as soon as construction funding is authorized. If MREFC funding begins in FY10, as requested in the proposal, then the NOAO engineering staff working on LSST will be transferred entirely to MREFC funding. Scientific staff is not included in the MREFC budget, and NOAO will continue to support those scientists working on the project. In the event that MREFC funding is delayed, NOAO will require bridge funding to cover the gap between the end of D&D (FY09) and the start of construction.



The exterior of the LSST "dome" and buildings as designed.

2. Provide science planning and opportunities for community participation by researchers at non-member institutions. NOAO scientists will lead and/or actively participate in the LSST science collaborations. These collaborations[4] are teams of professionals, each focused on one of the high priority science missions of the LSST. These teams are charged with

[4] The Science Advisory Council is chaired by Dr. Michael Strauss (Princeton University) and there are ten science collaborations: Weak Lensing, Strong Lensing, Supernovae, Large-scale Structure and Baryon Oscillations, Galaxies, Active Galactic Nuclei, Milky Way Structure, Stellar Populations, Transients/Variable Stars, and Solar System Science.

determining the requirements for carrying out each mission, planning precursor observations, simulating performance, providing feedback to the LSST through the Science Advisory Council, developing specialized software tools and pipelines that may be required, and organizing the core analysis to be performed with LSST computational facilities.

3. Plan the operations phase. The LSST will be sited on Cerro Pachón in Chile where NOAO/CTIO is well positioned to provide operations support. NOAO will work with LSSTC to establish an efficient operations model and will work with AURA, NSF, and the LSST Project to develop operations proposals that are consistent with LSST requirements and also optimize the use of the total NSF investment on Cerro Pachón and at CTIO.
4. Provide a scientific liaison to the LSST data management effort to coordinate NOAO DPP, NVO, and LSST efforts to identify collaboration opportunities and to prepare for LSST integration into the O/IR System.
5. Continue as an institutional member of LSSTC providing general oversight for the entire project. NOAO has a permanent seat on the Board of Directors.
6. Contribute to the development of an effective program of informal and formal LSST outreach (to be funded primarily via a separate LSSTC proposal to NSF) with continued information campaigns for the community and the general public.

In FY09, which marks the last year of D&D funding, the NOAO portion of the LSST D&D effort will require a total of $3.8M, with $1.9M from NOAO and the remainder from the NSF D&D funding. This budget supports 18 FTEs of scientific, engineering, and management staff; design contracts to external companies; and all other outside contracted services and hardware purchases needed to advance the design of the telescope and supporting facilities. All of the engineering staff (but not the scientific staff) and all other expenses for the LSST Project Team transition to construction funding as soon as it becomes available. The table below assumes these funds become available in FY10 and continue throughout the construction period. If this is not the case, then $3.2M in FY10 dollars will be required annually as bridge funding until construction funding begins.

The table below shows the total cost of the work being carried out at NOAO through a combination of funding from the NOAO operating budget and the D&D grant from NSF. The subsequent years show the costs assigned to the NOAO operating budget on the assumption that construction funding begins in FY10.

For the purposes of this Web posting, budget information is not available.

3.6 Public Affairs and Educational Outreach

The NOAO Office of Public Affairs and Educational Outreach (PAEO) conducts a comprehensive suite of formal and informal astronomy outreach programs designed to improve science education and expand public appreciation for astronomy on local, regional, national, and international scales. PAEO staff members are recognized leaders in their fields and have ongoing partnerships with most major observatories, space agencies, and astronomy education centers in the U.S. In addition, many new international partnerships are likely to emerge from extensive PAEO involvement in the planned International Year of Astronomy 2009.

3.6.1 Mission

In addition to providing support in outreach for the mission of NOAO, PAEO strives to advance the cause of science education and science inquiry in all sectors of American life, using the interdisciplinary appeal of astronomy and the unique facilities of NOAO.

PAEO programs regularly reach students across a wide range of ages and backgrounds. PAEO conducts programs for elementary school to high school and undergraduate students and plans to expand its offerings to graduate students. PAEO programs for the general public are intended to cut across the spectrum from Kindergarten age to 80+, from young families to international tourist groups, and from novice stargazers to advanced amateur astronomers.

PAEO programs designed to reach traditionally underserved groups such as Native Americans on the Tohono O'odham Nation and Spanish-speaking students and teachers in the Tucson and La Serena regions are gaining momentum and will receive even more attention in the coming five years. The active NOAO effort in media outreach will include regular use of new media (such as podcasts and video "vodcasts") and creative displays and activities at major community meetings such as those of the American Astronomical Society.

3.6.2 Major Goals of PAEO for FY2009–2013

- Continue PAEO's successful program, providing top-quality products and services in all of its education and outreach activities (formal and informal), incorporating the latest astronomy research results from the national observatory and Gemini wherever possible. Emphasize prototype activities, strategic team building and use of the latest educational research in PAEO programs.
- Expand the reach of PAEO programs into more diverse and underserved populations, including Hispanic audiences in the United States and Chile, rural schools in southern Arizona, and Native American audiences on the Tohono O'odham Nation. One particular new program to note in this area is the partnership with several historically black universities to enhance their undergraduate and graduate programs in astronomy.
- Initiate the expansion of the Kitt Peak Visitor Center, including an active membership program and separate fundraising effort to provide space for new and expanded public offerings, such as public lectures, cultural programs, and planetarium experiences.
- Initiate and develop a program of bilingual, cross-hemisphere, public outreach, telescope observing in the North and South for public outreach and educational programs, via newly Web-accessible public telescopes at the Kitt Peak Visitor Center and at the Cerro Mayu site.
- Develop new skills in the application of new digital media technology (distance learning, data visualization, podcasting, blogging, and interactive museum experiences).

- Participate actively in the organization-wide effort to engage the astronomical community, using PAEO'S expertise in both traditional and innovative media and its understanding of the entire NOAO program.
- Be a national and world leader in programs related to the IAU/UNESCO International Year of Astronomy 2009, including co-chairing the U.S. panel on public programs, serving on the main IAU working group, and leading key U.S. working groups on dark skies and optics education.
- Conduct an independent external review of NOAO PAEO programs in FY11.

3.6.3 Educational Outreach

NOAO Educational Outreach (EO) programs are designed to support and energize national science education reform efforts and the national science education standards, while being compatible with international educational programs. PAEO program staff have a keen awareness of their obligation to reach underserved groups.

Current and future NOAO EO efforts span the educational spectrum, including:

- Teacher professional development.
- Teacher-astronomer research partnerships.
- Instructional materials development.
- Informal and community-based science education.
- Research experiences for students and teachers.

Through the use of strategic partnerships, PAEO participates in larger projects where it can leverage resources, innovate, and play an intellectual leadership role:

- Strategic partnerships with agencies and professional societies such as the American Astronomical Society, the Astronomical Society of the Pacific (ASP), the American Geophysical Union, NASA, the Optical Society of America, and SPIE–The International Society for Optical Engineering.
- Cooperation with educational societies and organizations such as the American Association of Physics Teachers, the National Science Teachers Association, the National Earth Science Teachers Association, the Association of Science-Technology Centers, the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), and the International Dark-Sky Association.

Tohono O'odham Community College students in front of the newly painted 4-m dummy mirror.

- Active teaming arrangements with PAEO's closest geographic partners, including the Spitzer Science Center, the University of Arizona in general, and Steward Observatory and the Flandrau Science Center in particular.
- Multicultural activities in the Spanish language with astronomy materials and outreach programs in Chile and several emerging thrusts in Native American science education, such as on-going support for an introductory astronomy class at the Tohono O'odham Community College and optics education at the Boys & Girls Club in Sells.

NOAO also strives to be a leader in incorporating scientific data—and data tools like image processing—into the classroom. As new facilities produce prodigious amounts of data, NOAO will be exploring new methods of distributing and utilizing that data for educational purposes, leading toward the data-intensive era of LSST outreach. In addition, PAEO staff are actively developing new, high-quality, standards-based, inquiry-oriented materials needed by most of their educational programs.

Research Based Science Education (RBSE)
The RBSE program (formerly TLRBSE) is a cornerstone activity of NOAO educational outreach. Annually, RBSE competitively selects about 18 experienced middle school and high school teacher leaders from across the U.S. to receive advanced training in cutting-edge astronomical research projects. This training enhances their pedagogical and leadership skills, their content knowledge in astronomy and physics, and their grasp of computer-based tools such as data and image processing. PAEO sees the positive results of this program through the submission of student research papers to PAEO's on-line "RBSE Journal," as well as in the number and quality of science fair projects, both at the local and international (Intel) level.

In the next five years, PAEO will seek to maintain its ever-expanding cadre of trained master teachers (>140 and counting) by offering them fresh observing experiences (with student participation) on Kitt Peak, plus the use of small remote telescopes and access to cutting-edge astronomical facilities such as the Spitzer Space Telescope. PAEO may also seek to partner with specific regions or school districts that can provide their own financial support, or submit joint funding proposals to local educational foundations.

In addition, PAEO is undertaking a major effort to design a TLRBSE-like module for LSST educational outreach (using partial support from LSST D&D funds), centered on the idea of the classification of Near-Earth Objects, in connection with the Earth science requirements of middle schools.

Hands-on Optics
PAEO staff were the intellectual content leaders for an exemplary informal science project called "Hands-On Optics: Making an Impact with Light," with partners at the Optical Society of America and SPIE-The International Society for Optical Engineering, funded by the NSF Informal Science Education division.

PAEO intends to continue this program independent of OSA and SPIE (who are downsizing their outreach goals), including further development of the optics instruction modules (such as a kit on adaptive optics using partial support from GSMT outreach funds) and ongoing professional development support for this program, which has reached more than 20,000 middle school students in after-school programs and at science centers. This activity will become a core strength of PAEO.

Project ASTRO

Project ASTRO forms the core of NOAO's highly successful local/regional educational outreach program. Project ASTRO-Tucson (one of 13 national sites in a network implemented by the Astronomical Society of the Pacific) is a flexible program with broad content coverage and great utility for a diverse educational audience. In Tucson, it has been used successfully with elementary, middle, and high school students of different ethnic backgrounds, as well as with physically challenged and underserved students. ASTRO-Tucson has reached 30,000 students and counting, via more than 430 teacher-astronomer partnerships.

The program's main ongoing feature is the partnering of volunteer professional and amateur astronomers with K-12 teachers and community educators who want to enrich their astronomy and science teaching. The partnerships are developed through an annual training workshop, hands-on activities, effective educational materials, follow-up workshops, continued staff support, and connections to community resources.

The related Family ASTRO-Tucson will focus on continuing to reach a variety of underserved groups in the Tucson area, including the Tohono O'odham Indian Nation, the Hispanic community of the Sunnyside School District, and the Girl Scouts of America.

Spanish language astronomy education

In a further expansion of the ASTRO concept, NOAO North and South have jointly sponsored videoconference workshops for teachers in Tucson and La Serena. The teachers have exchanged methods and ideas about how to explain and demonstrate the nature of light and color to students of various ages, and conducted comparative research in dark skies, remote sensing, and the geology of Mars. Each workshop is held in Spanish with bilingual science teachers from the Tucson area; the latest project involves remote-sensing comparisons of the areas in and around the two cities.

The workshops are part of an even larger collaboration dubbed ASTRO-Chile. This effort is meant to take advantage of successful efforts in the United States, such as Project ASTRO, and efforts in Chile, like RedLaSer, by merging the strategies and techniques from each into a cross-cultural exchange.

In addition, a new base of operations just outside La Serena at a ranch house dubbed CADIAS (the "Centro de Apoyo a la Didáctica de la Astronomía") will provide a much-improved capability for astronomy teaching support and public star parties for the region. Future areas of emphasis will likely include the common issue of dark skies and light pollution, as well as sharing the experience of the skies of the other hemisphere with different audiences, including north-south partnerships for the International Year of Astronomy 2009.

Star party held at Centro de Apoyo a la Didáctica de la Astronomía (CADIAS) near La Serena, Chile

Other programs in Educational Outreach

"Astronomy from the Ground Up" is a collaborative effort between the Astronomical Society of the Pacific, NOAO, and the Association of Science-Technology Centers to provide professional development in astronomy for informal science educators nationwide. This NSF Informal Science Education (ISE) project conducts both face-to-face training and a distance-learning course. In the process, it is creating a network of science outreach professionals that PAEO will leverage greatly to expand awareness of its programs.

NOAO will continue as an active part of the nationwide GEMS materials network led by the Lawrence Hall of Science, and has helped establish a successful Southern Arizona GEMS Center, which provides professional development throughout the state of Arizona on guides for teachers developed by the Great Explorations in Math and Science program.

NOAO will continue as a partner on the University of Arizona NSF GK-12 Track 2 program "Collaboration to Advance Teaching Technology and Science (CATTS)." Two NOAO CATTS Fellows work each year to advance local and regional science teaching through a commitment of 15 hours per week.

GLOBE at Night has become an international phenomenon in just two years of worldwide dark-sky observing. PAEO intends to continue to grow this landmark "citizen science" program toward a full global effort with digital sky-brightness meters for the International Year of Astronomy 2009.

3.6.4 Undergraduate Education

NOAO has a long-standing commitment to undergraduate education, beginning with the pioneering summer program for Native American, Hispanic, and Black Undergraduates (NAHB) from 1980–1984, and since 1989, with the Research Experiences for Undergraduates (REU) program.

The NSF-funded NOAO REU program is recognized as a national leader. It has encouraged dozens of undergraduates—especially women, underrepresented minorities, and students from institutions lacking access to first-rate research staff and facilities—to pursue careers in science. The NOAO REU site programs at KPNO and CTIO provide a real-world context in which college students work as research assistants to NOAO astronomers on some of the major questions in current astronomical research.

NOAO currently is providing research experience to about a dozen undergraduates annually, and this rate is expected to continue, along with increased recruiting of underrepresented groups via expanded mailing lists and attendance at meetings of Historically Black Colleges and Universities (HBCUs), the Hispanic Association of Colleges and Universities, and the American Indian Science and Engineering Society. In Tucson, NOAO has also begun to include students with an interest in outreach, as a way of encouraging future careers in science education or joint research/outreach activities.

NOAO is beginning two collaborations: one with Fisk and Vanderbilt Universities, and one with South Carolina State University. Through proposals to NSF's new PAARE program, these collaborations will support both REU-like experiences for minority students and the possibility of ongoing mentoring of students leading up to doctoral dissertations. Even without the additional funding, NOAO has offered to host a limited number of such students as part of its REU activities.

3.6.5 Astronomy Education Review

The Astronomy Education Review (*aer.noao.edu*) is a refereed electronic journal that aims to bridge the gap between current astronomical research and science teaching, science learning, and broad science communications to the public. Conceived by Sidney Wolff and Andrew Fraknoi (Foothills Community College) as a lively compendium of research, news, and opinion, the journal has published five and counting virtual "issues" using start-up funding from NASA and core funding from NOAO for its editor. It has been endorsed by both the AAS and the ASP.

The on-going goals for AER during the next five years are to continue operations, automate the receipt and tracking of manuscripts to minimize the time required from the scientific editors, and find a long-term home and funding source for the journal. NOAO has fostered the AER since its inception, and PAEO will provide ongoing support for an editorial staff member and Web publishing until a long-term home is found.

3.6.6 Integration of Research and Education

By its very nature, a national observatory should encourage the integration of research and education. A key recent statistical study, and anecdotal evidence, suggests strongly that NOAO facilities and staff are playing an increasingly important role in this area.

A recent review (by J. Mould and D. Brouillette) of the use of NOAO telescopes by graduate students during the period 1997–2006 found that NOAO retains a significant, and apparently growing, role in graduate education. Over these nine years, 362 U.S. graduate students from 71 Ph.D.-granting universities used one or more NOAO telescopes for thesis research. These numbers appear to be rising by at least 5% per year; this is a faster rate than the growth of NOAO observing proposals overall, which have averaged a little under 4% growth per year over the period 2002–2006. This contrasts with the numbers of astronomy theses tracked by the American Institute of Physics (AIP), which shrank by almost 3% per year between 1998 and 2004.

At the other end of the university pipeline, NOAO continues to recruit top-flight students for its Research Experiences for Undergraduates (REU) programs. Over 85% of the KPNO REU alumni have gone on to do graduate research in astrophysics or are working in astronomy-related fields; the numbers at CTIO are likely very similar.

In high schools, PAEO now offers continuing opportunities for RBSE teacher alumni (see below) to observe with their students at Kitt Peak on the WIYN 0.9-m and 2.1-m telescopes and the McMath-Pierce Solar Telescope. Eighteen of these teachers (and counting) have had the unique opportunity to observe with the Spitzer Space Telescope; this joint program with SSC is continuing, with additional support and research possible for six more teachers from the NASA WISE Explorer spacecraft to be launched in 2008.

In addition, public programs at the Kitt Peak Visitor Center Observatory are evolving toward research-like experiences, including remote use of the 20-inch telescope once it is automated in 2007.

PAEO staff are prepared to extend this training in observational astronomy to college undergraduate and graduate students in the form of short-course winter workshops, given the necessary resources, university interest, and telescope observing time.

3.6.7 Public Outreach

NOAO's Public Outreach group manages all activities at the Kitt Peak Visitor Center, including the center's educational exhibits and retail operations, three daily tours of Kitt Peak observatories, the Kitt Peak docent/volunteer program, educational programs for visiting school classrooms and the general public, and the popular nighttime observing experiences for both the general public and advanced amateurs at three small public observatories on Kitt Peak. Public outreach staff also participate in several informal outreach programs based in the PAEO educational outreach group, including Family ASTRO and local use of a mobile planetarium.

Kitt Peak attracts more than 50,000 tourists annually. The Visitor Center serves as the hub for all of these visitors, providing information, services, and educational activities on the mountain. NOAO is executing a series of significant upgrades to the Visitor Center facility, with new audio-visual displays and updates to its colorful display posters, along with the addition of more hands-on exhibits and interactive activities led by docents.

The Kitt Peak Nightly Observing Program (NOP) is a fee-based program aimed at introducing the general public to the wonders of astronomy. The NOP is one of the most popular educational attractions at Kitt Peak, with more than 40,000 participants since its inception in 1996. The Advanced Observing Program (AOP) is also a revenue-generating program targeted to amateur astronomers interested in observing with a large telescope and state-of-the-art instrumentation. The AOP is an all-night observing session that uses the Visitor Center telescope outfitted with a CCD camera operated with the help of an NOAO Public Outreach telescope observer.

These unique and popular programs attract participants from around the world and receive positive publicity in both tourism and amateur astronomy publications. Overall, the daily revenues generated by the Visitor Center attendees and programs help to offset about 80% of the costs of NOAO's Public Outreach activities.

Over the next five years, major expansion of the Kitt Peak Visitor Center and its associated programs is planned, including new exhibits and a greater variety of products for sale.

In addition to the regularly scheduled NOP/AOP programs, the Visitor Center conducts special observing events throughout the year, including public sessions for astronomical events such as meteor showers and lunar eclipses. With the approval of NSF, the NOAO Public Outreach group has begun to establish a membership program at Kitt Peak. In return for a nominal membership fee, the members of this program receive a newsletter, opportunities to experience special events, and discounts on Visitor Center programs; more than 150 individuals and families have signed up, and PAEO intends to grow this program further.

The NOAO Public Outreach group will also continue to work with the Southwestern Consortium of Observatories for Public Education (SCOPE), a cooperative of research institution-based visitor centers in the Southwest that promotes public awareness of astronomy through access and education.

Specific public outreach goals for the next five years include (1) automation of the visitor center 20-inch telescope dome for remote access, (2) an expanded selection of tours of the Kitt Peak facilities, (3) educational "camp" and school programs on Kitt Peak, and (4) development of a training center for public outreach.

3.6.8 Media Outreach and Public Information

More frequently than any other scientific field, astronomy and related topics such as planetary science are the subject of regular front-page newspaper coverage and analogous interest from major television and radio news outlets. In combination with material posted simultaneously on the Internet, these media stories provide an extreme “multiplier effect” that can bring the latest exciting scientific results to the attention of millions of people around the world.

NOAO generates an average of one press release per month, and imagery from NOAO research telescopes and its public outreach telescopes is often featured on popular sites such as the “Astronomy Picture of the Day” and the Space.com image of the day. NOAO also will continue to expand its capabilities in Webcasting, podcasting, blogging, and related technologies.

Related efforts include a major exhibit presence at each biannual meeting of the AAS, based on the latest imagery and scientific results being presented at the meeting by NOAO. By working closely with the AAS press officer and by active networking with the astronomy-oriented news reporters who attend each meeting, NOAO will continue to produce significant science news coverage in major media outlets.

The NOAO Image Gallery (*www.noao.edu/image_gallery*) is accessed regularly by textbook writers, museum researchers, the media, and the public, as evidenced by a daily stream of requests for image-use permission and frequent use of NOAO imagery by the popular Web sites. NOAO intends to redesign the presentation of this archive on the Web for greater eye appeal and usability, while expanding its holdings by increasing interaction with researchers at CTIO and with the users of the Gemini telescopes.

The NOAO home page on the Web will be redesigned to serve its dual purposes: (1) efficient access to up-to-date information and announcements for the research community, and (2) an engaging and clear site for the public at all levels.

The future goals of NOAO—and the observatory’s more aggressive role in fostering the U.S. System—are an integral part of the NOAO/NSO Newsletter. This quarterly publication (circ. 2,300) continues to serve as a lively and graphically attractive source of key information for NOAO’s many disparate customers, partners, and public stakeholders. NOAO imagines extending the Newsletter by developing a more frequent, electronic version that will provide a succinct but eye-catching glimpse into the most important scientific, technical, and political stories that affect NOAO and its users.

3.7 Long Term Plans beyond the Proposal Period

As we look beyond the period covered by this cooperative agreement, the astronomical landscape will have evolved dramatically. These are the changes that will impact our discussions with the community about how our program must evolve:

- The time domain frontier will be opened, first via operation of Pan-STARRS and the Dark Energy Survey, and soon thereafter by LSST, resulting in demand for world-wide follow-up observations (some on timescales as short as a few hours) with a wide range of telescopes and instrumentation.
- ALMA will be in full operation, providing not only new insights into early galactic and stellar/planetary system evolution, but the need for complementary O/IR observations, particularly with large telescopes equipped with AO-fed imagers and spectrographs.

- JWST will begin its operation phase, placing requirements both on ground-based follow-up observations (particularly with multi-object NIR spectrographs and high resolution mid-IR imagers and spectrographs operating in concert, first with 8- to 10-m class telescopes, and soon thereafter with ELTs) and precursor surveys to select prime JWST targets.
- The era of ELTs will be but a few years in the future, with the consequent need for extensive suites of instruments and AO systems to exploit the enormous increases in sensitivity and angular resolution afforded by these next generation telescopes.
- Telescope archives will evolve to the point where their content will be essential to planning new observations, and their richness so great as to enable multiple high-impact scientific investigations by investigators located throughout the world.

As the astronomical landscape changes, so must NOAO in order to fulfill its mission of enabling the U.S. community to carry out world-competitive frontier research. In order to anticipate these changes, NOAO will need to work with the community to understand their impact and change the mix of skills represented among its scientific, engineering, and project management staff to match the challenges of the future.

4 NOAO MANAGEMENT PLAN

4.1 Scientific Staffing Plan

The scientific staff at NOAO has three primary functional responsibilities. First, a high-quality scientific staff that is intimately familiar with the telescopes and instruments available is required to assist our community if the facilities are to be used effectively and efficiently. Second, because the future plans for NOAO rely heavily on partnerships for the provision of new capabilities, it is essential that the staff responsible for developing these partnerships be respected by their peers and able to work collegially with them. Third, the scientific staff plays an essential role in long range planning by anticipating what new facilities will be required as scientific opportunities evolve.

Research at NOAO is a derived function. Scientific staff are chosen because they can carry out essential service functions. There must, however, be sufficient research opportunities to enable the recruitment and retention of staff with the very high level of skills and knowledge required to carry out the functional responsibilities. It is important to note that some of the research programs pursued by NOAO staff, such as the development of supernova monitoring techniques, which led to the discovery of dark energy, are among the most important scientific advances in the last decade; five current or former NOAO staff members were honored among the recipients of the 2007 Gruber prize for the discovery of dark energy.

Independent observatories have comparable scientific staff needs, which are met by the observers at the host institutions themselves. However, NOAO cannot rely on the user community to provide essential services. With only one or two observing runs per year being typical, and with Gemini run almost entirely in queue mode, community observers cannot acquire a deep knowledge of the instruments and telescopes.

The scientific staffing plan that NOAO has developed takes into account all of the functional tasks that must be carried out in order to support the facilities that the community currently has access to: Gemini, CTIO, KPNO, and TSIP observatories. The plan also supports: (1) the evolution toward major facilities (GSMT and LSST), which will take place during the period of this cooperative agreement; (2) a larger investment in archiving and data management, both in order to make coherent data sets from existing facilities widely available and to prepare for the LSST era of massive databases; and (3) active engagement with the university community in a variety of instrumentation and telescope partnerships. Thus, the plan presents a level of staffing for the steady state, which, as explained at the end of this section, is somewhat higher than the current level.

In the sections below, functions are grouped together into logically associated activities that require significant effort. Thus, there was no attempt to estimate that “this task requires 0.15 FTEs” and total these up to come up with a scientific staff total. That approach suffers not only from the difficulty (or variability) of estimating how much effort each task takes, but also requires finding exactly the right mix of staff to carry out the diverse and complex mix. The tables refer to number of staff members, not FTEs.

The management model within NOAO is one in which scientific and technical staff work closely together to implement the overall program. A senior scientist/manager heads each major functional area and supervises not only the scientific staff listed here but also all of the technical supporting staff. The scientific staff is responsible for establishing the scientific requirements for new projects, both hardware and software, and acting in effect as systems engineers during the implementation phase. Scientists also evaluate the performance of deployed systems, telescopes, instruments, and data management tools to ensure that the requirements continue to be met over the full life cycle.

4.1.1 Mechanics of Reporting

AURA and NOAO policies establish two tracks for scientists. The "astronomer" track requires 50% time on functional responsibilities; the "scientist" track requires 80% time on functional responsibilities. The astronomer track includes a tenure decision, while the scientist track proceeds through a series of term appointments. The reason for having the two parallel tracks is to attract, retain, and reward two different types of scientific staff. The astronomer track staff are primarily focused on the broad external community and are most similar to a university astronomer who splits time equally between teaching and research. The scientist track staff are more focused on facilities and equipment. They tend to have greater technical knowledge and their research is more likely to be in technical areas. Both types of staff are necessary to the successful operation of NOAO.

All NOAO staff, including scientific staff, fill out timecards, which provides the means to track how they spend their time in order to understand the costs of each activity and program. Scientific research is maintained as a separate category, and, together with "professional development" and "external service," it can be used to assess what fraction of a scientist's time is spent on activities other than functional support. Scientists are asked to record the true number of hours worked, so, even though their salary is nominally based on an 80-hour biweekly pay period, the hours they work can be substantially more than this. In general, scientists work 85–95 hours in each pay period, and they spend a smaller fraction of time on their research than the allowance for their position. Thus, in NOAO's external reporting, time charged to grants and functional duties is counted first, and then time charged to research, up to a limit of 80 hours per pay period is counted.

Because of the necessity of having an active scientific staff to carry out many of the activities in the NOAO program, the cost of the research time of scientific staff is included in the cost of each program. Thus, if a program uses 50% of the functional time of an astronomer-track staff member, that program is also charged for 50% of the research time of that staff member. This approach acknowledges the true cost of using scientific staff.

4.1.2 Operating Observatories: Scientific Staffing

As described in other sections of this proposal, the major support for U.S. users of Gemini, apart from the telescope operations, comes from the NOAO scientific staff. For the users of CTIO and KPNO, the NOAO scientific staff is responsible for ensuring that the telescopes and instruments perform at scientifically acceptable levels. These observing support groups must be responsive to the user community in a timely manner because of the fixed schedules for observing

Function	Gemini	CTIO	KPNO
Telescope Performance		1	1
IR Imaging	1	1	1
IR Spectroscopy	1	1	1
Optical Imaging	1	1	1
Optical Spectroscopy	1	1	1
AO	1		
SOAR Agreement		1	
Scientist/Manager	1	1	1
Total	**6**	**7**	**6**

applications and observing runs. Therefore, the extent to which operations support personnel are shared across sites is minimized.

Specific tasks for the Gemini support group include operation of the helpdesk, technical assistance in preparing observing proposals, technical reviews of the feasibility of all U.S. proposals in advance of the TAC meetings, advice on Phase II preparation, assistance at the telescope with a sufficient number of observing runs to remain familiar with instrumental capabilities and limitations, preparation of materials for AAS meetings, and weekly staff meetings with the international project. Most of these same duties, apart from the preparation of Phase II proposals and the meetings with the international project, apply to CTIO and KPNO as well; and for these two observatories, NOAO scientists are also responsible for providing all documentation, assisting observers at the telescopes when necessary, evaluating instrument performance, and recommending improvement and upgrades. Because community use of AO, which will become an important part of the Gemini arsenal, will require substantial support for planning and interpreting observations, an AO expert has been added to the staffing plan for Gemini. At CTIO and KPNO, an optics expert has been added who will be responsible for optical alignment, control systems, and other aspects of telescope performance. The agreement with SOAR requires that NOAO supply a dedicated scientist for support of operations.

4.1.3 New Telescopes

The NOAO role in GSMT during the early part of the period covered by this proposal is to monitor the developments within each of the two large-telescope projects in order to evaluate the likely returns of a major national investment in both. In order to provide the two projects with confidence that sensitive information will be properly protected, interactions with each project will be led by different scientists.

Function	GSMT	LSST
Science Working Group	2	1
Technical Monitoring	2	
Technical Development		
Telescope Scientist		1
Data Management Scientist		1
Scientist/Manager	1	1
Total	**5**	**4**

A proposal to construct the LSST has been submitted to the NSF. In it, NOAO's responsibilities are clear: construction of the telescope and development of the site, including provision of the project scientist for this area of activity; leadership of the group working on stellar populations; membership on the science advisory committee, ensuring that community requirements for useful access to useful data are met; and planning for operations. Funding for scientific staff at the LSST member institutions was not included in the proposal to NSF.

4.1.4 Partnerships

The model proposed for NOAO development relies extensively on close working partnerships with the community. Establishment of sound partnerships and successful implementation of the agreed upon programs requires a substantial amount of time, usually of fairly senior staff, to work out arrangements that are mutually beneficial. NOAO envisions establishing a System of telescopes, whereby the community gains access to a full range of capabilities at all apertures. NOAO also believes

Type of Partnership	No. of Scientists
Small Telescopes	1
Intermediate Telescopes	1
Instrumentation	2
Detectors/Controllers	1
Scientist/Manager	1
Total	**6**

it to be critical to achieving the desired levels of performance that there be coordinated efforts in the acquisition, characterization, distribution, and operation of both optical and IR detectors.

4.1.5 Data Management

The key tasks in data management are to develop and maintain the NOAO archive and to gain the experience needed to ensure that the LSST archive can be easily accessed and used effectively by the community. There are three major phases of data management for the NOAO archive: (1) making sure that useful data from the telescopes flows smoothly into the central processing system, a process that requires scientific leadership in defining the types of information that will be delivered by the instruments, calibration procedures, quality assessment, etc.; (2) pipeline processing of the data ingested with appropriate quality assurance; and (3) enabling interfaces, query tools, and documentation that make it possible to use the archived data. NOAO also expects to provide assistance to users through a helpdesk and personal interactions.

Function	No. of Scientists
Data Ingest	1
Pipeline Operation	1
Database/Data Extraction	1
User Support (including IRAF)	2
Scientist Manager	1
Total	**6**

4.1.6 PAEO

The NOAO Public Affairs and Educational Outreach Department (PAEO) provides national leadership by developing and providing high-quality astronomy education programs for a wide set of audiences. The audience matrix spans pre-Kindergarten to elder hostel programs (“K to Grey”) and encompasses local, regional, national, and international audiences.

PAEO programs span the range from public information to general public tours and observing with telescopes to research experiences for students/teachers, citizen-scientists, and undergraduates (including use of space observatories such as the Spitzer Space Telescope and WISE). These programs cover informal science centers and museum and after-school programs. For formal education, instructional materials and curriculum development are critical areas well suited for NOAO’s mission, and there is a particular emphasis on developing programs that emphasize acquisition and use of research data. As in most formal programs, professional development of teachers is highly emphasized.

Function	No. of Scientists
Manager of Science Education in PAEO	1
Leader of RBSE and related research programs	1
Science mentor(s) to RBSE/research programs	0.5–1
Leader of technology/optics education and related programs	0.5–1
Instructional Materials Development	1
Site managers for NSF REU programs	0.5
Total	**4.5–5.5**

Why must NOAO’s PAEO department cover such a wide range of activities? First, NOAO has a responsibility as a national observatory to reach as wide an audience as practical. Second, projects often span multiple topic areas and audiences. Third, programs that can be tested and delivered locally often lend themselves to broader distribution nationally and even internationally. Testing and formative evaluation of new programs is often best done locally. Finally, expertise in these educational areas behaves synergistically—knowledge in one specialty or with one audience has broad positive effects in helping develop expertise in other areas. (In practice, the current NOAO education group members all possess a wide repertoire of expertise and educational training.)

All current PAEO educational outreach staff members on the scientific staff (~4.5 FTE equivalents) have a core competency in astronomical research (all have Ph.D. degrees in astronomy, astrophysics, or planetary geophysics). This is necessary to support several key research-related programs, including Astronomy Research Based Science Education (RBSE), the Spitzer Research Program for Students and Teachers and our WISE teacher research program.

Additional valuable areas of expertise: Liaison to the System/University Outreach Support, 0.5–1 FTE; and educational research, 0.5–1 FTE.

4.1.7 Miscellaneous

The TAC process involves receiving and evaluating over 800 proposals annually, with TAC meetings held twice each year; informing observers of the outcome of their proposals; working with the Gemini International TAC to schedule the selected U.S. programs; and scheduling all of the NOAO telescopes. The TSIP program involves not only receiving and reviewing proposals, but also overseeing work on the selected proposals and providing enough information/documentation to the community so that they can make effective use of small amounts of observing time at the private observatories.

Function	No. of Scientists
NOAO Director	1
TAC (Review/Scheduling)	1
TSIP (Selection/Oversight/User Support	1
Support for staff science research	1
Total	**4**

These staffing levels have been determined by the expertise required and by the desire to minimize dividing staff among many small unrelated duties, which has been found to be inefficient. The numbers have not been increased to allow for substantial research time, nor are any post-doctoral positions included. NOAO believes that in order to be attractive to the caliber of scientists required to lead an effective national observatory, there must be a minimum of 25% of their time available for research (current AURA policy for tenure track scientists is 50%, but time cards show that the actual time spent is closer to half this amount), and it will be a challenge for management to ensure that the NOAO scientific staff has sufficient time and support to continue productive research careers.

During the five years covered by this proposal, the astronomical landscape will change dramatically as outlined elsewhere in this proposal. These changes will require an expansion of the NOAO scientific staff or, if some of the programs/tasks above are eliminated, an evolution of the scientific staff. LSST should be nearing first light, and NOAO will have to ramp up the scientific effort in this area to support effective community use of the flood of data that will be produced and specifically to support time domain astronomy. Adaptive optics will become increasingly important, and NOAO will require more expertise in this area. The use of archived data will become an increasingly important component of research programs, and curation of ground-based data is a challenging problem that will grow with the advent of ever-larger detectors, and this may require increases in the data management staff. Even though we expect most instrumentation to be built in partnership with the community, NOAO staff must spend a substantial amount of time in order to realize these partnerships. Several steps are involved in developing a partnership. First, we must have a clear sense of what would most benefit the user community, which involves engaging users in long range planning. Then, it is likely to require explorations with several different groups to establish a single partnership that is mutually beneficial. After a partnership is agreed upon in principle, there is still the need to develop conceptual designs, develop sound management plans, conduct design reviews, estimate costs, write proposals, and provide sufficient oversight to ensure that the work meets performance, schedule, and cost constraints. NOAO at its current staffing level can explore only one or, at most, two options at any one time. Additional expertise in this area will be required when the much more complex instrumentation for ELTs becomes a primary activity for the community.

The total staff count from the tables above is 49. Since staff spend 50% or 80% of their time on functional support activities, depending on whether they are astronomer-track or scientist-track, this total represents about 35 FTEs of scientific staff effort. As a check on this approach, the following table represents an estimate of the scientific staff effort in FTEs needed to carry out each of the programs in the steady state, i.e., categorized by program rather than activity. This table was constructed from a bottom-up analysis of the individual tasks within each program by the associate directors and heads of the programs. The total FTE count, 37.62, is consistent with the estimate constructed through the tables above.

Program	Sci. Staff FTE
Kitt Peak National Observatory	4.55
Cerro Tololo Inter-American Observatory	5.20
NOAO Gemini Science Center	5.43
System Development Office	1.05
System Instrumentation	2.75
GSMT Program Office	4.00
Data Products Program	4.00
NOAO LSST Program	2.66
Science Research Support	0.40
Public Affairs and Educational Outreach	5.00
NOAO Director's Office	1.30
NOAO-S Director's Office	1.28
Total	**37.62**

The conclusion from these analyses is that the current staff size of 41 astronomer-track and scientist-track personnel, who provide approximately 28 FTEs of functional effort, is too small to carry out this program. This is due in part to not having replaced a substantial number of staff who left or retired during the last few years. Consequently, this deficit can be addressed through some new hires, combined with reassignment of some of the existing staff. A search for additional scientist-track staff is in progress.

4.2 Technical Staffing Plan

The engineering and technical staffs at NOAO have three primary responsibilities. First, a highly trained and motivated core of engineers and technicians is needed for support and renewal of the operating mountain observatories, CTIO and KPNO. Second, NOAO's new System Division will require considerable engineering and technical support in its activities. Third, the LSST design development phase will need continuing effort from NOAO engineers and technicians prior to the commencement of MREFC funding for the construction phase. This technical staffing plan takes into account each of these general areas, as well as the details of individual projects and support needs within each one. It also recognizes the value added by allowing these talented people to work across boundaries in the organization chart whenever appropriate as well as the opportunities for professional growth that such flexibility can offer.

This staffing plan was developed in a zero-based, bottom-up process that considered the expected support workloads and project needs for the next five years. It began with a careful look at the existing support requirements for the two mountain sites, paying careful attention to where support work could be reduced or made more efficient, and also to areas where current staff are overloaded and need more help with essential tasks. Then each development area and expected project throughout NOAO was examined for expected workload, starting from a blank slate and estimating what effort was needed to do each item. The estimates were developed in considerably more detail than is shown here, to ensure their realism and to get some idea of the uncertainties in the estimates. It is important to remember, however, that these are only estimates. They suffer from some internal uncertainties, and they will be subject to unpredictable external influences. The estimated labor needs were rounded to the nearest whole full-time equivalent (FTE) to avoid giving a false impression of deterministic certainty. A summary of the estimates by NOAO division and by skill class is given in the table on page 74.

4.2.1 CTIO and KPNO

The needs of the operating observatories begin with regular continuing operations. Both sites need a broad spectrum of skills to maintain and operate the telescopes and instruments for which they are responsible, which includes both those directly owned and operated by CTIO and KPNO, as well as the telescopes in which they are significant partners—SOAR and WIYN. CTIO also supports the SMARTS telescopes, and KPNO provides some support services to tenant observatories. The necessary skills include those of senior engineers in all disciplines from mechanical to software, those of specialized technicians for vacuum-cryogenic infrared instruments, and those of skilled and experienced mechanical and electronic generalists. The needs of the two sites are very similar but not completely identical as there are some differences between the telescopes and instruments each site must support. The total FTEs needed per year for this support work are about 21–23 for each site, with little change expected from year to year.

During the term of this cooperative agreement, CTIO and KPNO will be undertaking a number of projects aimed at renewing their infrastructure and modernizing their equipment. These projects respond to the concerns expressed in the Senior Review report that the mountain sites were falling behind in scientific productivity and efficiency due to a lack of recent investment. Both sites will be dedicating significant effort and capital investment to this program of improvements over the next few years. Many of the projects will be common between the two sites, thus allowing some economies of scale and reuse of design work. For example, both sites plan to develop new telescope control systems for their flagship 4-m telescopes; the Blanco and Mayall telescopes are not completely identical, so there will be some differences in the implementations of these new control systems, but much of the design work will be common and shared between them. Similarly, both sites are interested in developing a common observing software environment to improve observing efficiency by providing observers with a consistent, intuitive interface regardless of instrument or telescope. Most of this work will be common and shared between the two sites. Another, somewhat different project calls for the replacement of all the current detector controllers on facility instruments with modern, modular MONSOON systems for greater observing efficiency and ease of maintenance. Here there will be some common experience that will benefit both sites, but much of the actual work will be local to each site with less opportunity for savings. Finally, each site has its own list of needed capital upgrades to computer, power, ventilation, and drive systems, and so on, which will be essentially unique to that site. These projects will be more capital-intensive than regular operations, but they will require considerable support from in-house engineering staff, including mainly electronics and software engineers, with some oversight from experienced systems engineers. Again, the needs and levels of needs from the two sites will be very similar but not identical. In rough terms, the FTE requirements are expected to be about 4–7 FTEs per year per site, with some variations from year to year and site to site as projects ramp up and ramp down naturally.

4.2.2 System Division

NOAO's new System Division will encompass the Data Products Program, the System Instrumentation Program, the System Development Office, the Telescope Systems Instrumentation Program (TSIP), the GSMT Program Office, and the TAC operations.

The Data Products Program will be developing data handling systems for NOAO and other system telescopes; developing and supporting data pipelines, data management tools, and scientific analysis routines; and carrying out other tasks in support of the VO and the connections of O/IR System telescopes to the VO. For all this work, they estimate a need for about 11 FTEs of software engineers and operations support personnel.

The System Instrumentation Program will be completing the SOAR Adaptive Optics Module (SAM), completing the development of MONSOON controllers for System telescopes, carrying out technology development programs as identified by various System committees, and taking part in instrumentation partnerships with other System institutions. This program's estimated needs are for about 14 FTEs per year of engineers and technicians across the skill spectrum.

The System Development Office will be coordinating and supporting community efforts to define the needs of the national System of telescopes at all apertures, and the scientists there will need some engineering support to help carry out the cost-benefit trade studies that will be needed to inform community discussions. The estimated engineering needs here are about 2 FTEs per year spread over several different engineering skills.

TSIP will continue its efforts to ensure renewal of instrumentation on large telescopes in the national System. A small amount of engineering effort, estimated to be 0.5–1 FTE per year of engineers in various disciplines, will be needed for participation in design reviews and other oversight activities.

Similarly, the GSMT Program Office will, among many other things, be monitoring progress of the U.S. ELT projects, for which a small amount of engineering effort will be needed for participation in design reviews and evaluation of project progress. The GSMT Program Office will also continue its support of site study efforts and analysis of site study data. For all these tasks the estimated need for engineering support totals about 6 FTEs per year.

The TAC activities are not expected to require any engineering support.

4.2.3 LSST

NOAO's team supporting the LSST design development phase will continue its efforts to advance the design of the telescope, the mount, the enclosure, and the associated control systems and interfaces. This effort will continue to be supported from NOAO's base budget until the MREFC funding becomes available, after which the effort will be ramped up and the costs will be transferred to the project construction budget. This effort is estimated to require about 14 FTEs per year of engineers and technicians across the skill spectrum.

4.2.4 Summary

The following table shows a summary of the expected engineering and technician effort needed by skill class and by NOAO Division. These estimates are for FY09 only (the first year of the proposed renewal). There will be variations in subsequent years as discrete projects are started and finished, and as NOAO adjusts its focus in response to community input over time. The overall totals are not currently expected to change much, as NOAO expects to manage the staff flexibly by assigning people across divisional boundaries whenever appropriate. The largest expected change will be the transfer of the LSST staff from the NOAO budget to the LSST construction budget when the MREFC funding begins to flow. The large number of software engineers shown in the System Division is the sum of the entire effort by two groups: (1) Data Products Program software engineers who are primarily engaged in pipelines, archives, and data reduction and mining; and (2) the System Instrumentation staff who provide instrument control software.

Technical Staffing Allocations By NOAO Division

Skill Class	CTIO	KPNO	System Division	LSST
Project/Engineering Manager	0	0	1	1
Systems Engineer	1	1	0	1
Optical Engineer	1	0	1	2
Mechanical Engineer	2	3	3	2
Electronics Engineer	5	4	5	1
Software Engineer	6	6	17	5
Mechanical Designer	0	1	2	2
Electronics Designer	1	0	1	0
Optics & Coatings Technician	1	0	0	0
Electronics/Instrument Technician	10	8	4	0
Mechanical Technician	4	3	0	0
Instrument Maker/Machinist	1	1	2	0
Totals	**32**	**27**	**36**	**14**

4.3 U.S. Astronomical Community—Engaging Them and Understanding Their Needs

A challenge of working with as diverse a community as NOAO's is connecting to it effectively. The community of researchers who use NOAO facilities includes great ranges of research interests, stage of career, and expectations for NOAO. Some, who are at institutions that own and operate their own facilities, would like NOAO to provide a mechanism for federal participation in projects of extremely large scale. Others depend on access to the current NOAO facilities to carry out their own research and to train their students.

Both of these types of activities must be carried out if NOAO is to "provide community access to an optimized suite of high-performance telescopes of all apertures." Consequently, NOAO's program is also diverse, and continually evolving, as strategic opportunities appear and projects are completed. How can the community be kept apprised of the activities and plans of the NOAO program? How can the NOAO management get sensible feedback from the community and use it to guide the program?

Traditionally, NOAO has depended on a newsletter (available both in paper and electronic form), a Web site, and a booth at AAS meetings for keeping the community aware of its program. Of course, documents such as the Annual Program Plan and Long Range Plan and presentations to committees such as the NOAO Users' Committee, the AURA Observatory Council, the AURA member representatives, and the NSF Program Review Panel also serve to publicize this information. Input comes predominantly from these committees and from informal discussions with individuals, and is generally limited to particular areas within the program.

In this new cooperative agreement, NOAO would like to extend the methods both for distributing information and for gathering input. The fact that the NSF Senior Review, based on input from the community, arrived at a balance so different from that proposed, as well as their apparent perception of ineffectiveness and inefficiency, suggests that there is substantial room for improvement in communications. NOAO acknowledges that there are never enough resources to do everything that everyone wants, and that the people who believe that not enough resources are being dedicated to their priorities will be the most vocal. However, having a justifiable and accountable process for developing the balance among the priorities is essential for the success of the System and of NOAO.

In order to keep the community informed about the NOAO program, NOAO will explore the following mechanisms:

- Staff presentations about the NOAO program at regional sites or large astronomy departments.
- A recorded, downloadable video presentation on the NOAO program available on the Web.
- A summary version of this proposal distributed broadly.
- Renewed focus on presenting the entire NOAO program at AAS meetings, including occasional town hall meetings.
- Regular, short, email newsletter "broadcasts."
- Presentations to national committees that set or influence policy.

Similarly, NOAO will investigate several new means for soliciting community opinion:

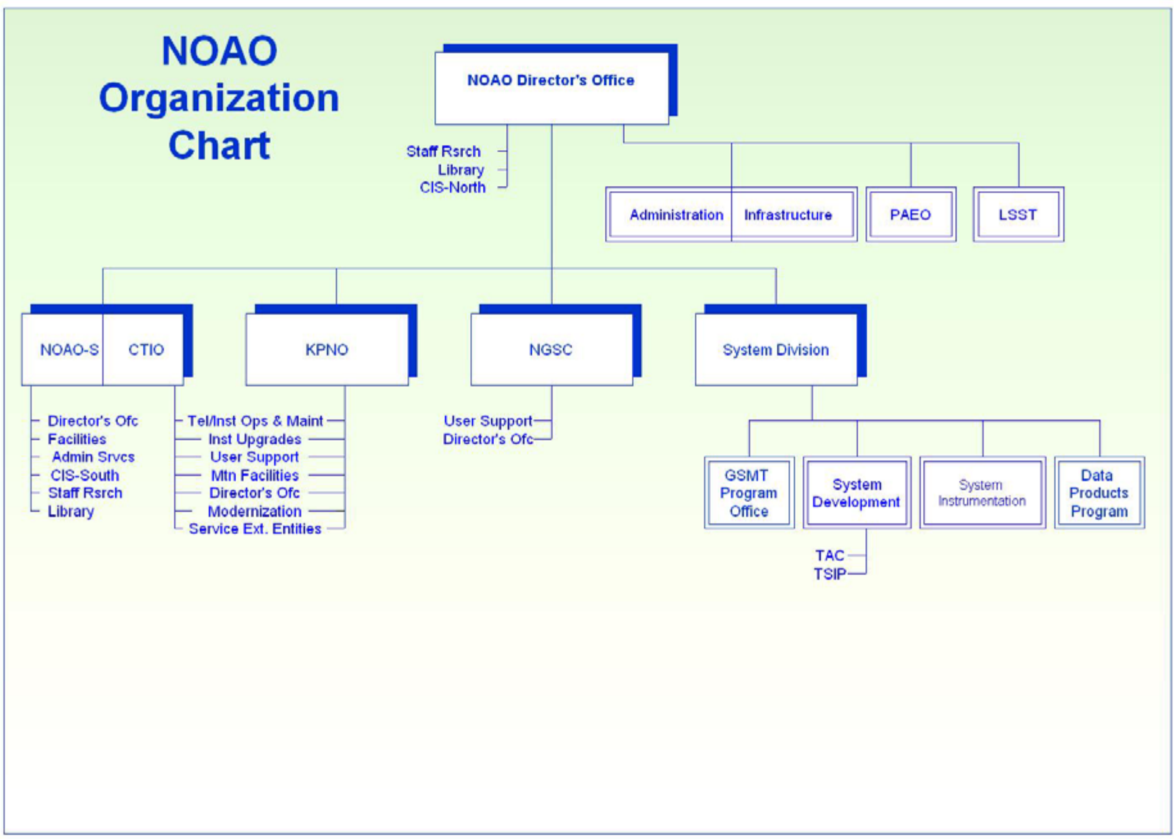
- Electronic surveys.
- Regional town meetings.

- An NOAO-wide user helpdesk.
- Panels commissioned to study well-defined problems and make recommendations.

Of course, many of these have been used with varying degrees of effectiveness in the past, but this aspect of NOAO's program, getting the message out and engaging the community, will now figure prominently in its strategic planning discussions.

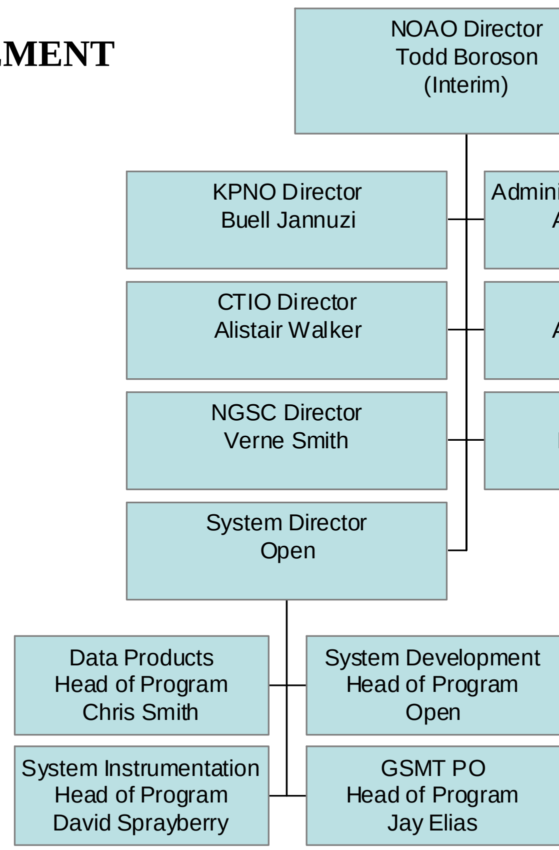
4.4 NOAO Divisional Structure

The change in the NOAO program is accompanied by a change in NOAO's organizational structure. The creation of a System Division will provide a focus for both internal and external discussions about the System and its evolution as motivation for decisions and priorities. This will allow one overarching goal, the effectiveness of the System in addressing the community's needs, to guide the program. The System Division will gather together the activities that are driven by scientific goals, but are not constrained to a single observatory: System Instrumentation, Data Products, System Development, TSIP administration, the GSMT Program Office, and the Telescope Time Allocation Process. The other three pre-existing divisions, KPNO, CTIO, and NGSC, will remain. Administrative and infrastructure programs will be run directly out of the director's office: in Tucson, the NOAO Director; and in La Serena, the CTIO Director. The La Serena infrastructure programs are termed NOAO-South, and are distinguished from the CTIO program. This should allow simpler and clearer comparison of the CTIO and KPNO activities.



A Director heads each of the three "observatories," KPNO, CTIO, and NGSC. These Directors are active astronomers, selected through a national or international search by a search committee comprising both internal and external members. The CTIO Director also has responsibility for the NOAO-South infrastructure support. A System Division Director joins these directors in the new structure. A "Head of Program" leads each program within the System Division. The two remaining Associate Directors are the Associate Director for Public Affairs and Educational Outreach and the Associate Director for Administration and Facilities. These two retain the title Associate Director because they represent the organization externally. Those who are solely responsible for internal programs have the title Head of Program. This creates a more logical matching of function and title. All of these top management personnel make up the NOAO Executive Council, which meets monthly for organization-wide planning and decisions. The following figure shows the current personnel in these top management positions. A search is currently under way for the NOAO Director.

NOAO MANAGEMENT



Each program has scientific, technical, and administrative staff associated with it. Some of the staff, particularly the scientists, have responsibilities in more than one program. Although this can be difficult to manage, it gives personnel a better appreciation of the breadth of the program and the organizational goals. The table below shows the total number of FTEs and the number of FTEs of scientific staff functional effort that is allocated in the FY08 budget and program plan. The scientific staff research effort is included in the total FTE count. The final column shows the result of each associate director or head of program assessing the steady-state level of scientific staff effort needed to carry out each program. Some of the difference between the current available level of effort and the desired steady-state level is a consequence of recent attrition; some is a result of intended changes in the program.

Observatory or Program	FY08 Total FTE	FY08 Scientist FTE	Desired Steady-State Scientist FTE
NOAO Director's Office	26.1	1.2	1.30
CTIO	50.5	4.0	5.20
KPNO	65.9	3.5	4.55
NGSC	11.1	4.8	5.43
GSMT Program Office	13.8	2.0	4.00
System Development	4.3	0.8	1.05
System Instrumentation	19.6	2.2	2.75
Data Products Program	19.2	3.4	4.00
NOAO LSST Program	12.2	1.7	2.66
Science Research Support	2.4	0.4	0.40
Public Affairs and Educational Outreach	33.4	3.6	5.00
Central Administration and Facilities	30.6	0.0	0.00
NOAO-South Infrastructure	13.0	0.7	1.28
Totals	**302.1**	**28.3**	**37.62**

4.5 NOAO Business Plan FY2009–2013

NOAO's business plan provides a balance among programs that evolves to allow the following:

1. A "bump" in the KPNO and CTIO budgets over the years FY09–11 that funds the modernization of these facilities and the renewal of their infrastructure. In FY09-corrected dollars, the additional integrated investment totals about $5M per site. Following that effort, the annual budget of each observatory returns to a level about $600K (FY09) higher than the pre-modernization level.

2. An increasing level of support for developing and implementing new programs that will create a more robust and capable System for the community.

3. A degree of flexibility in business and infrastructure support to accommodate the challenge of operations in two hemispheres and the revenue impacts of transitions of NSO and LSST. Note that there is a substantial financial uncertainty associated with operation in Chile that is borne by NOAO. In particular, the risk associated with both long-term and short-term variation in the dollar-peso exchange rate (which, in recent years, has reflected the weakening dollar) is not negligible.

4. The establishment of an appropriately-sized GSMT Program Office, with the subsequent possibility of expanding technical efforts that would benefit all ELT projects.

The chart below summarizes the NOAO budget evolution over an eight-year period.

For the purposes of this Web posting, budget information is not available.

4.5.1 Annual Allocated Costs by Divisions

In response to the Senior Review recommendations, NOAO began restructuring its organizational, staffing and program budgets. The resulting "Work Breakdown Structures" (WBS) present a clear view of the programs over the course of the proposal period. The new WBS table splits the NOAO program into north and south. All of the individual programs, aside from KPNO and CTIO, have some effort at each of the two sites. The activities within the new System Division are shown individually. The true cost of scientific staff effort is now included in the budget of each program. This new table provides a clearer view of KPNO and CTIO operations, NGSC Gemini Support Operations, the development of the System and Administration/Infrastructure for NOAO North and NOAO-South, and major projects such as LSST. The development of costs presented have been twofold: first, historical costs (including operating a facility in Chile) in combination with zero-based reviews were used to review the existing and new programs; second, a newly developed staffing model was used in conjunction with the projected needs to develop the System and observatory modernization programs. The five year projections take into account the changes in program needs with a flat budget increasing by 3% for inflation. Anticipated changes in outside support costs (indirect revenue) from both NSO and LSSTC and the LSST MREFC funding have a direct affect on operations and infrastructure. These are reflected in the base budgets beginning FY10. Costs of each current or planned program include estimates of both payroll and non-payroll costs.

4.5.2 WBS Work Package Definitions

Observatories

- Kitt Peak National Observatory (KPNO): includes Telescope and Instrument Operations/Maintenance, Instrument Upgrades, User Support, Mountain Facilities, KPNO Site Director's Office, Scientific Staff Research, Servicing External Entities (Tenant support, overall site maintenance, etc.), and Modernization Upgrades per the Senior Review recommendations.
- Cerro Tololo Inter-American Observatory (CTIO): includes Telescope and Instrument Operations/Maintenance, Instrument Upgrades, User Support, Mountain Facilities, CTIO Site Director's Office, Scientific Staff Research, Servicing External Entities (Gemini, overall Tololo operations, etc.), and Modernization Upgrades per the Senior Review recommendations.
- NOAO Gemini Science Center (NGSC): includes Gemini user support North and South, Instrument upgrades and support, NGSC Director's Office/Program Management, Fellowships, Scientific Staff Research.

System Division

- System Development Office (SDO): includes the Telescope Allocation Committee (TAC), leadership of planning activities for System capabilities, and implementation of TSIP and other programs that develop or strengthen the System.
- System Instrumentation (SI): includes re-organized instrumentation program supporting NOAO, the System, and the community. Also includes MONSOON and instrumentation maintenance support.
- Giant Segmented Mirror Telescope Program Office (GSMTPO): includes the management of the newly reorganized program office to support the community's interests in and access to future ELTs, community input to science working groups, and instrumentation and technology development. NOAO will provide oversight for the NSF GSMT development funds and interaction with the GSMT community.
- Data Products Program (DPP): includes data management and support. Continuing to archive and distribute data and data products from KPNO and CTIO and integrate with new instruments, enabling ground-based O/IR community involvement and data in NVO, work with instrument groups to facilitate incorporation of System data into archives and build support for LSST research.

Current Projects, Science Research Support, Public Outreach

- Large Synoptic Survey Telescope (LSST): includes the NOAO program management and technical support portion of the NSF Design and Development Program. NOAO emphasis is on telescope design and site support. Support design and development effort until MREFC funding begins. Provide scientist contribution during construction era, ramping up of data products participation, and the development of an NOAO role in operations era.
- Science Research Support (SRS): includes the direct support to science staff, including administrative support, colloquiums, travel, page charges, and conferences/workshops. Also includes salary support for fellowships, those science staff on sabbatical, and staff who administer the support activity.
- Public Affairs and Educational Outreach (PAEO): includes general public affairs office, Kitt Peak Visitor Center and gift shop operations, night programs on KPNO, various outreach

programs including RBSE, Hands-on Optics, Project ASTRO, Chilean programming, and REU. Scientific staff research for the scientific outreach staff and community informational programming such as the newsletter, science announcements, etc.

Administration and Infrastructure

- NOAO Director's Office (NDO): includes NOAO Director's office support and observatory-wide operations (North and South), such as libraries, risk management, and corporate and agency interactions.
- Central Administrative Services (CAS): includes NOAO-wide business management and budget, accounting, human resources, sponsored projects, procurement, import/export, and shipping/receiving. Also includes costs for administrative needs at NOAO-South for international operations. Support for AURA corporate, Gemini, NSO, and LSSTC is provided in this work-package.
- Central Facilities Operations (CFO): includes utilities, building maintenance and support, vehicles, safety and plant and equipment for Tucson and La Serena.
- Computer Infrastructure Services (CIS): includes NOAO-North and NOAO-South support for hardware/software, network, bandwidth, and communications.
- AURA Facilities and Administrative Fee (F&A): includes DCAA approved rates and management support fee and other support by AURA directly to NOAO.

4.5.3 Funding Allocation Distribution by Work Packages

The following tables represent the funding allocation distribution for the five full years of the cooperative agreement beginning March 2009 through March 2014. Fiscal year funding begins October 1 of each year, therefore, years FY09 and FY14 represent 1/2 fiscal year funding due to the anticipated start and ending date. However TSIP funding is an annual fund and, therefore, is represented in full year funding. Furthermore, as the program plans are developed, adjustments to individual work-packages are made in accordance with each year's program plan. Annual carry-forward may occur due to the actual program implementations and adjustments. The carry-forward is not known until the program year is completed, therefore, it is not shown in the tables. If and/or when it occurs, the funds will be needed in the next fiscal year to continue the planned programs as described in the proposal.

For the purposes of this Web posting, funding information is not available.

5 GOALS AND METRICS

5.1 Broader Impacts

The re-organization of NOAO staff and budget resources around the central theme of the System (including the creation of the System Development Office) produces an overall architecture for the national observatory that inherently sets "broader impacts" as the primary organizational goal.

At its most basic level, this system of broader impacts begins with the historic and continuing mission of NOAO as the provider of thousands of hours of annual telescope observing time on the basis of proposals solicited widely from the community twice per year. It includes operating NOAO telescopes and their instruments at a level of excellence, reliability, and scientific productivity that matches any observatory in the world. More recently, the NOAO mission has grown to encompass storing and distributing the resulting individual observations and survey data from these telescopes (and related metadata) on a daily basis.

NGSC exists primarily to guide the U.S. community toward the best possible use (and, hopefully, the broadest impact) of the Gemini Observatory. The PAEO group conducts a widely known and respected set of formal and informal public outreach and education programs, which span the range from telescope tours, exhibits, and press releases to creative hands-on workshops, teacher professional development, and unique in-depth observing experiences at Kitt Peak for students, educators, and the public.

The following chart shows the broader impacts that occur as part of the current day-to-day NOAO program (✓ = significant contribution, ✓✓ = major outcome of the program).

Broader Impact **--------------** **NOAO Program**	**Help Advance Scientific Discovery**	**…while Promoting Teaching, Training, Learning**	**Broaden Participation of Under-represented Groups**	**Enhance Infrastructure**	**Results Disseminated Broadly to Enhance Understanding**	**Benefits to Society**
Ph.D. student observers + Goldberg Fellows	✓✓	✓	✓		✓	✓
KPNO/CTIO	✓✓		✓	✓✓	✓✓	✓
NGSC	✓✓		✓	✓	✓	✓
DPP	✓✓	✓	✓✓	✓✓	✓✓	✓
Instrument Program	✓		✓	✓✓	✓	
GSMT	✓✓		✓	✓✓	✓	✓

Broader Impact -------------- NOAO Program	Help Advance Scientific Discovery	…while Promoting Teaching, Training, Learning	Broaden Participation of Under-represented Groups	Enhance Infrastructure	Results Disseminated Broadly to Enhance Understanding	Benefits to Society
LSST	✓✓		✓✓	✓✓	✓	✓✓
TSIP	✓		✓✓	✓✓	✓	
AODP	✓✓		✓	✓✓	✓	
Scientific Staff	✓✓	✓	✓	✓		✓
Public Info/Web		✓	✓	✓	✓✓	✓
Educational Outreach	✓	✓✓	✓✓	✓	✓	✓✓
KP Visitor Center & programs		✓	✓✓	✓	✓	✓✓
Chile outreach	✓	✓✓	✓✓	✓		✓✓
IYA 2009	✓	✓	✓✓	✓	✓✓	✓✓

NOAO proposes to expand the broader impacts of its program in the following major ways:

1. Renewed and revitalized infrastructure at KPNO and CTIO designed to improve the efficiency and effectiveness of every observing program.
2. A dynamic, ongoing discussion with the community regarding NOAO support for the System, and the best mix of scientific instruments to be deployed across it.
3. Community access to DECam and ODI.
4. Enhanced capabilities at Gemini including NICI, GSAOI, and GPI, marketed more aggressively to the U.S. community.
5. A new GSMT Program Office designed to maximize scientific benefit to the community and to the NSF from the development and funding of the next generation of extremely large telescopes and related instruments.
6. Support for successful MREFC funding and subsequent construction for the LSST, perhaps the ultimate System facility, along with ongoing development of scientific collaborations with the community and effective planning for the operations era.
7. Consistently high-quality capture, storage, and distribution of ground-based O/IR data from NOAO telescopes and others throughout the System, plus related scientific support.

8. A cohesive and intuitive O/IR node of the NVO that opens new research opportunities for researchers, students, and educators everywhere.
9. Project oversight and technical support for new science instrumentation partnerships with universities, private observatories, and other elements of the U.S. System, and related opportunities for educational training.
10. Instrumentation technology development for the System in areas such as optical coatings, detectors, and controllers.
11. More focused efforts to create research mentorships and REU-like experiences for physics and astronomy students from minority institutions.
12. Automated telescopes in both hemispheres for remote public outreach and education, with an emphasis on previously underserved audiences.
13. An increasing number of outreach programs designed for Native American audiences and educators, and for underserved schools in rural areas in the U.S. Southwest.
14. Expanding support for a Spanish-language, astronomy-oriented, outreach center in Chile, focused on a largely underserved population.
15. A wider range of public programs and events at an expanded Kitt Peak Visitor Center and a related partnership with the proposed University of Arizona science center in downtown Tucson.
16. Leadership of U.S. national efforts for creative and engaging public programs related to the International Year of Astronomy 2009, including a new cheap telescope kit capable of being reproduced in quantities of millions.

5.2 NOAO Program Goals and Milestones

Each of the NOAO programs has goals that are aligned with achieving the mission of “providing access to an optimized system of high-performance telescopes of all apertures, and to the data from them, for the benefit of the entire community.” These goals must make progress towards an overall improvement of the System, while at the same time, responding to the Senior Review recommendations.

KPNO and CTIO goals for this period are:

- Renewal of their facility infrastructure to support efficient operations for the foreseeable future and to allow the deployment of new state-of-the-art capabilities.
- Restoration of community access to the maximum practical level together with a renewed focus on scientific and technical support.
- In partnership with the System Instrumentation Program and potential external partners, develop and deploy new capabilities to address the needs of the community.

NGSC goals for this period are:

- Continued provision of access to the Gemini telescopes for the U.S. community and the support needed to use that access effectively.
- Effective advocacy for the U.S. community within Gemini, bringing a System perspective to discussions with the community and with the Gemini partners and Observatory.

- Bring the expertise and experience acquired through interaction with Gemini and the queue-scheduled observing system to help other observatories understand how to implement alternate observing modes.

System Instrumentation program goals for this period are:

- Develop or maintain expertise in areas that will provide significant assistance to instrumentation efforts throughout the System.
- Support the positive evolution of the System by participating proactively in instrumentation strategic planning.

Data Products program goals for this period are:

- Represent and advocate the interests of the ground-based O/IR community within the developing National Virtual Observatory.
- Bring data management and computational efforts to bear in facilitating the incorporation of data System-wide into NVO-compliant archives.

GSMT program office goals for this period are:

- Engage the community in the development of a broad design reference mission and in the understanding of the capabilities needed to carry it out. Successful accomplishment of this will lead to a re-endorsement of GSMT by the next decadal survey.
- Represent community interests in all projects to build extremely large telescopes.
- Advise the NSF on partnership opportunities.

System Development program goals for this period are:

- Effectively carry out the existing programs that provide access to all the facilities within the System.
- Organize and lead discussions, both external and internal, aimed at developing a clear understanding of the capabilities needed by the community, and devise and implement new programs to provide these capabilities.

LSST program goals for this period are:

- Support the design and development phase for the project, providing effort towards the telescope and site, in preparation for the start of construction with MREFC funding.
- Provide community liaison for involvement in the science collaborations.
- Plan the operations phase, including the development of a model for community access to the data, together with required tools and support.

Public Affairs and Educational Outreach program goals for this period are:

- Expand the reach of PAEO programs into more diverse and underserved populations.
- Initiate the expansion of the Kitt Peak Visitor Center.
- Develop and carry out a strong program for the International Year of Astronomy 2009.

5.3 Reviewing NOAO's Performance

This proposal describes a program for NOAO that effectively addresses the goals listed in the solicitation. For each of these goals, both the identified actions that demonstrate the relevance of the proposal to the goal and metrics for assessing NOAO's success in meeting that goal are presented.

1. Develop and employ effective mechanisms for engaging the observatory's full range of stakeholders in order to ensure that NOAO facilities, services, and programs best reflect the community's evolving needs and priorities.
   - Effective mechanisms for engaging stakeholders will come from a renewed emphasis on communicating with the community as well as ongoing discussions with the NSF/AST staff. Our oversight committees, the AURA Observatory Council and the NSF Program Review Panel, and our Users' Committee provide additional linkages with more focused, smaller groups.
   - Metrics will include monitoring of telescope oversubscription rates as an indication that demand for facilities, services, and programs is increasing. Of particular note is the current low oversubscription rate for the smaller telescopes, which NOAO hopes to increase by improving the quality of the instrumentation and performance.
2. Operate and modernize the existing observational facilities and computational infrastructure and ensure that the primary criterion for their utilization be the scientific merit of the proposed research as judged by appropriate, merit-based review processes.
   - Modernization of the existing observatories is a stated priority, and substantial funding has been directed to initiate a comprehensive plan of renewal.
   - The fraction of telescope time given out through merit-based peer review is reported annually. It typically runs 95–99%. The small fraction that is allocated as Director's Discretionary Time is used primarily to ensure that NOAO staff are expert users of the equipment that they support. NOAO telescope time allocation process is reviewed regularly, and special programs such as surveys or joint time with NASA space facilities are discussed regularly by oversight groups and the NOAO Users' Committee.
3. Assure productive and efficient research access by the U.S. astronomical community to the twin telescopes of the international Gemini Observatory through merit-based review processes.
   - Gemini oversubscription rates indicate that the Gemini capabilities are much in demand by the community.
   - Monitoring of the number of papers published annually by U.S. users of Gemini (and ultimately, citation rates and impact measures) will demonstrate the productivity of this facility and of the community's access.
4. Serve as the steward of high quality scientific data from the above facilities on behalf of the U.S. communities, through pipelines, reduction processes, dissemination, and archiving.
   - The success of NOAO's Data Products Program in achieving these goals will be measured through the volume of archived data holdings, the rate at which raw data can be processed, and the amount and variety of data downloaded by users.

5. Develop and incorporate new capabilities, such as telescopes, instruments, and services, at the existing observatories as required by the U.S. astronomical and solar communities, within available resources, to ensure community access to state-of-the art facilities and support.
    - Following the report from the ReSTAR committee, NOAO will conduct internal and community-based discussions to identify the capabilities that are needed and the best way to provide them.
    - NOAO's success at developing and providing new capabilities will be reflected in future community discussions, ranging from a continuing series of workshops on the System to the next Senior Review.
6. Implement strategic partnerships with U.S. universities, federal, non-federal, and international entities, specifically including the Telescope System Instrumentation Program, that will enhance the scientific capabilities available to the entire astronomical and solar communities.
    - NOAO will continue to administer the Telescope System Instrumentation Program to enhance scientific capabilities and to provide community access to the System. A healthy level of oversubscription for TSIP subawards and the non-federal telescope time will demonstrate the continued effectiveness of this program.
    - Beyond TSIP, there is an opportunity for additional partnerships to leverage the non-federal funding that has been raised to build and operate a substantial number of small and mid-sized telescopes. Development and implementation of a successful program will result in a significant increase of nights for the community.
    - As has been the case throughout the past five years, NOAO will seek partnerships to contribute to the building of new instruments—both to bring new resources into the System and to assist other institutions in retaining strong instrumentation teams.
7. Represent NSF in community-based planning, design, and development efforts for potential new federally-funded initiatives in ground-based, optical and infrared astronomy and in solar physics.
    - NOAO's efforts in large national initiatives will be closely tied to and supportive of NSF's plans for community participation.
    - New major facilities receiving federal funding and coming into operation will indicate success in addressing this goal.
8. Support the education and development of the future workforce for astronomical and solar sciences including, in particular, those groups that are underrepresented in the U.S. science workforce.
    - The training of the next generation of astronomical researchers and teachers will continue as a priority, with particular emphasis on underrepresented groups.
    - Metrics of success will include numbers of students whose research depends on NOAO data and of minority students who participate in NOAO's undergraduate research experience programs.
9. Recruit and develop an outstanding scientific staff to execute innovative science programs at NOAO that demonstrably support the community-based research carried out at these facilities.

- Metrics include the number of current and past NOAO scientific staff members whose contributions to the community are notable, including observatory directors, membership on national panels and committees, and high-visibility research teams.

10. Propose a plan, in consultation with AST, for expeditious implementation of the recommendations of the 2006 AST Senior Review.
    - This entire proposal represents a plan for implementation of the recommendations of the Senior Review. Priorities for the use of resources, changes in program goals, and a closer engagement with the community all flow from our interpretation of the Senior Review.
    - This plan is a result of ongoing consultation with NSF/AST staff, starting from before the public release of the Senior Review report.
11. Integrate research and education for the benefit of the public through a program of education and public outreach.
    - A combination of press releases on exciting and important research from NOAO's facilities, along with the incorporation of new data products into NOAO's educational program indicate successful integration of these two elements.
12. Provide for management and budget autonomy of NOAO and NSO.
    - NOAO's five-year budget plan as presented in this proposal acknowledges the separation of NOAO and NSO.
13. Propose a plan for NSO to establish itself as an independent observatory with a consolidated headquarters facility, tied to an appropriate milestone in ATST development.
    - Not applicable.
14. Manage the NOAO staff and all activities carried out at the observatories according to current best practice and in full compliance with all relevant laws and regulations, maintaining quality and relevance in administration and management in a cost-effective manner.
    - Regular reviews such as the 2006 NSF Management Review and the 2007 cost review conducted as a recommendation of the Senior Review provide opportunities for ensuring that NOAO's management is efficient. In addition, the newly reinitiated Visiting Committee will provide a deeper inspection of the way NOAO operates as an organization.

ABBREVIATIONS AND ACRONYMS

3-D	3-dimensional
2MASS	2-Micron All-Sky Survey
AAS	American Astronomical Society
AAT	Anglo-Australian Telescope
ACCORD	AURA Coordinating Council of Observatory Research Directors
Admin	Administration
AER	Astronomy Education Review
AFRL	Air Force Research Laboratory
AGN	Active galactic nucleus (or nuclei)
AIP	American Institute of Physics
ALMA	Atacama Large Millimeter Array
ANDICAM	A Novel Double-Imaging Camera
AO	Adaptive optics
AODP	Adaptive Optics Development Program
AOP	Advanced Observing Program
ASP	Astronomical Society of the Pacific
AST	NSF Division of Astronomical Sciences
ASTRO	(Not an acronym)
ATM	Atmospheric Sciences (Division of NSF)
ATST	Advanced Technology Solar Telescope
AURA	Association of Universities for Research in Astronomy
BBSO	Big Bear Solar Observatory
BTC	Big Throughput Camera
CA	Cooperative Agreement
CADIAS	Centro de Apoyo a la Didáctica de la Astronomía
CAS	Central Administrative Services
CATCH	Community Access Telescope Clearing House
CATTS	Collaboration to Advance Teaching Technology and Science
CCD	Charge-coupled device
CDM	Cold dark matter
CD-ROM	Compact Disk – Read Only Memory
CELT	California Extremely Large Telescope

CfA	Harvard Smithsonian Center for Astrophysics
CfAO	Center for Adaptive Optics
CFO	Central Facilities Operations
CFOH	Central Facilities Operations and Headquarters
CIS	Computer Infrastructure Services
CLEA	Contemporary Laboratory Exercises in Astronomy
CMEs	Coronal Mass Ejections
CoDR	Conceptual Design Review
CoI	Co-investigator
CoSEC	Collaborative Sun-Earth Connection
CTIO	Cerro Tololo Inter-American Observatory
CXO	Chandra X-ray Observatory
D&D	Design and Development
DASL	Data and Activities for Solar Learning
DCAA	Defense Contract Audit Agency
DECam	Dark Energy Camera
DES	Dark Energy Survey
DIMM	Differential Image Motion Monitor
DLSP	Diffraction-Limited Spectro-Polarimeter
DMAC	Data Management and Analysis Center (GONG)
DoD	Department of Defense
DOE	Department of Energy
DPP	Data Products Program
DRM	Design Reference Mission
DST	Dunn Solar Telescope
EGSO	European Grid of Solar Observations
EIS	Environmental Impact Statement
ELT	Extremely large telescope
EO	Educational outreach
EPO	Educational and Public Outreach
ESA	European Space Agency
ESF	Evans Solar Facility
ESO	European Southern Observatory
ESSENCE	Equation of State: SupErNovae trace Cosmic Expansion

ET	Exoplanet Tracker
ETS	Engineering and Technical Services (NOAO)
F&A	Facilities and Administrative
FDP	Full-Disk Patrol
FLAMINGOS	Florida Multi-object Imaging Near-infrared Grism Observational Spectrometer
FLAMINGOS-2	(Second FLAMINGOS instrument for Gemini, see above)
FOV	Field of View
FTE	Full Time Equivalent
FTEs	Full Time Equivalents
FTS	Fourier Transform Spectrometer
FY	Fiscal year
GB	Giga Bytes
GEMS	Great Explorations in Math and Science
GLAST	Gamma-ray Large Area Space Telescope
GMT	Giant Magellan Telescope
GONG	Global Oscillation Network Group
GPI	Gemini Planet Imager
GSAOI	Gemini South Adaptive Optics Imager
GSFC	Goddard Space Flight Center (NASA)
GSMT	Giant Segmented Mirror Telescope
GSMTPO	Giant Segmented Mirror Telescope Program Office
HAO	High Altitude Observatory
HBCU	Historically Black Colleges and Universities
HQ	Headquarters
HST	Hubble Space Telescope
HVAC	Heating, Ventilating, Air Conditioning
IAU	International Association of Universities
IBIS	Interferometric BIdimensional Spectrometer (Arcetri Observatory)
ICD	Interface Control Document
IDL	Interactive Data Language
IfA	Institute for Astronomy (University of Hawai`i)
IGM	Intergalactic medium
IHY	International Heliophysical Year
Info	Information

Infr	Infrastructure
IR	Infrared
IRAF	Image Reduction and Analysis Facility
IRMOS	Infrared Multi-Object Spectrograph
ISE	Informal Science Education
ISOON	Improved Solar Observing Optical Network (now OSPAN)
ISS	Integrated Sunlight Spectrometer
IT&C	Integration, Testing, & Commissioning
IYA	International Year of Astronomy
JHU	The Johns Hopkins University
JWST	James Webb Space Telescope
KP	Kitt Peak
KPNO	Kitt Peak National Observatory
KPVT	Kitt Peak Vacuum Telescope
LAPLACE	Life and PLAnets Center (University of Arizona)
LGS	Laser guide star
LRP	Long Range Plan
LSST	Large Synoptic Survey Telescope
LSSTC	LSST Corporation
LTE	Local Thermodynamic Equilibrium
LWS	Living With a Star
MCAO	Multi-Conjugate Adaptive Optics
MCC	Maui Community College
McMP	McMath-Pierce Solar Telescope
MEDB	Maui Economic Development Board
MHD	Magnetohydrodynamic
MIP	Major Instrumentation Program
MKIR	Mauna Kea Infrared
MONSOON	(Not an acronym.) A scalable, multi-channel high-speed array controller and image acquisition system
Mosaic	The NOAO CCD wide-field imager having 8192 x 8192 pixels (also called CCD Mosaic Imager)
MOU	Memorandum of Understanding
MREFC	Major Research Equipment and Facility Construction (NSF)
MRI	Major Research Instrumentation (NSF)

NAC	NSO Array Camera
NAHB	Native American, Hispanic, and Black Undergraduates
NAI	NASA Astrobiology Institute
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NDO	National Optical Astronomy Observatory's Director's Office
NDSC	Network for the Detection of Stratospheric Change
NDWFS	NOAO Deep Wide-Field Survey
NEO	Near-Earth Object
NEWFIRM	NOAO Extremely Wide-Field Infrared Imager
NGC	New General Catalog
NGO	National Gemini Office
NGSC	NOAO Gemini Science Center
NHPA	National Historic Preservation Act
NICI	Near-Infrared Coronagraphic Imager
NIO	New Initiatives Office
NIRI	Near-InfraRed Imager
NJIT	New Jersey Institute of Technology
NLFF	Non-Linear Force-Free
NLTE	Non-Local Thermodynamic Equilibrium
No.	Number
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NOAO-N	National Optical Astronomy Observatory-North
NOAO-S	National Optical Astronomy Observatory-South
NOP	Nightly Observing Program
NRC	National Research Council
NSF	National Science Foundation
NSF/AST	National Science Foundation, Division of Astronomical Sciences
NSF/ATM	National Science Foundation, Division of Atmospheric Sciences
NSO	National Solar Observatory
NSO/SP	National Solar Observatory Sacramento Peak
NSO/T	National Solar Observatory Tucson

NVO	National Virtual Observatory
O/IR	Optical/Infrared
ODI	One Degree Imager
OMB	Office of Management and Budget
OPCC	Oficina de Protección de la Calidad del Cielo
OPTIC	Orthogonal Parallel Transfer Imaging Camera
OSA	Optical Society of America
OSIRIS	Ohio State InfraRed Imager/Spectrometer
OSPAN	Optical Solar Patrol Network (formerly ISOON)
PAARE	Partnerships in Astronomy & Astrophysics Research and Education
PAEO	Public Affairs and Educational Outreach
Pan-STARRS	Panoramic Survey Telescope & Rapid Response System
PCA	Principal Component Analysis
PDR	Preliminary Design Review
Ph.D.	Doctor of Philosophy
PI	Primary Investigator
PIO	Public Information and Outreach
PRVS	Precision radial velocity spectrometer
PSPT	Precision Solar Photometric Telescope
RA/Dec	Right Ascension/Declination
RASL	Research in Active Solar Longitudes
RBSE	Research Based Science Education
RedLaSer	Red de Estudiantes de La Serena
ReSTAR	Renewing Small Telescopes for Astronomical Research
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RFI	Request for Information
RISE/PSPT	Radiative Inputs from Sun to Earth/Precision Solar Photometric Telescope
RMS	Root-Mean-Square
ROSA	Rapid Oscillations in the Solar Atmosphere
SACNAS	Society for the Advancement of Chicanos and Native Americans in Science
SAM	SOAR Adaptive Module
SCB	Sequential Chromospheric Brightening
Sci Ops	Science Operations

Sci Rsrch	Science Research
Sci.	Scientific
SCOPE	Southwestern Consortium of Observatories for Public Education
SDO	Solar Dynamics Observatory
SDO	NOAO System Development Office
SDSS	Sloan Digital Sky Survey
SFC	Space Flight Center (NASA)
SI	System Instrumentation
SINGG	Survey for Ionization in Neutral Gas Galaxies
SMARTS	Small and Moderate Aperture Research Telescope System
SN	Supernova (or supernovae)
SNIa	Supernovae type Ia
SOAR	Southern Astrophysical Research
SOC	Solar Observatory Council (AURA)
SOHO	Solar and Heliospheric Observatory
SOI	Solar Oscillations Investigations (SOHO)
SOLIS	Synoptic Optical Long-term Investigations of the Sun
SONG	Stellar Oscillation Network Group
SOT	Solar Optical Telescope
SPD	Solar Physics Division (AAS)
SPIE	Society of Photo-optical Instrumentation Engineers
SPINOR	Spectro-Polarimeter for Infrared and Optical Regions
SR	Senior Review
SRA	Summer Research Assistant
SRD	Science Requirements Document
SRS	Science Research Support
SSC	Spitzer Science Center
SST	Swedish Solar Telescope
SSWG	Site Survey Working Group (ATST)
STEP	Summer Teacher Enrichment Program
STEREO	Solar TErrestrial RElations Observatory
STScI	Space Telescope Science Institute
SWG	Science Working Group
Sys Dev	System Development

TAC	Telescope Time Allocation Committee
TB	Tera Bytes
TCS	Telescope Control System
Telops	Telescope operations
TLRBSE	Teacher Leaders in Research-Based Science Education
TMT	Thirty Meter Telescope
TRACE	Transition Region and Coronal Explorer
T-ReCS	Thermal-Region Camera Spectrograph
TSIP	Telescope System Instrumentation Program
U.K.	United Kingdom
U.S.	United States of America
UA	University of Arizona
UBF	Universal Birefringent Filter
UNESCO	United Nations Educational, Scientific and Cultural Organization
UPS	Uninterruptible power supply
USAF	United States Air Force
VCCS	Virtual Camera Control System (Dunn Solar Telescope)
VO	Virtual Observatory
VSM	Vector Spectromagnetograph
VSO	Virtual Solar Observatory
WBS	Work Breakdown Structure
WFMOS	Wide-field multi-object spectrograph
WHIRC	WIYN High-resolution Infrared Camera
WISE	Wide-field Infrared Survey Explorer
WIYN	Consortium consisting of the University of Wisconsin, Indiana University, Yale University, and NOAO
WWW	World Wide Web

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H. FACILITIES

AURA currently operates NSF-owned NOAO and NSO facilities and AURA-owned facilities in the United States and Chile, which will continue to be used under the proposed cooperative agreement.

The primary NOAO facilities include the NOAO/NSO operations offices and laboratories in Tucson, AZ; the Kitt Peak National Observatory (KPNO); and the Cerro Tololo Inter-American Observatory (CTIO). NOAO operates the Mayall 4-meter telescope; the 3.5-meter WIYN telescope, in cooperation with the WIYN partners; the 2.1-meter telescope; and a Visitor Center on Kitt Peak, which is located about 55 miles southwest of Tucson, AZ.

CTIO is located in northern Chile with operational offices in La Serena, Chile. Cerro Tololo Inter-American Observatory is located about 52 km ESE of La Serena. At this site in Chile, NOAO operates the Blanco 4-meter telescope and, in conjunction with the SOAR partners, the 4.1-meter SOAR telescope. Through the SMARTS consortium, NOAO also operates 1.5-meter, 1.3-meter, 1.0 meter, and 0.9-meter telescopes. In Chile, AURA has title to certain real and personal property, use of which has been granted to the NSF in support of CTIO or for such other astronomical uses as approved by the NSF.

NSO content is not available for viewing on this Web site.