# TABLE OF CONTENTS

EXECUTIVE SUMMARY ...............................................................................................................1

1. A SCIENCE DRIVEN PROGRAM ........................................................................................2
   Where We Are Today, 2
   The Next Decade, 3
   LSST and GSMT, 4
   Data Products Program (DPP), 4
   KPNO, CTIO, and Gemini, 5
   Major Instrumentation Program (MIP), 5
   Public Affairs and Educational Outreach, 7
   The NOAO Scientific Staff, 7

2. THE NATIONAL OBSERVING SYSTEM ..........................................................................10
   NOAO Gemini Science Center, 10
      Major Program Goals FY 2004 – 2008, 10
      Science Direction, 10
      User Support, 11
      Operations Support, 11
      Instrumentation Development, 11
      Building the Gemini Community, 12
   Cerro Tololo Inter-American Observatory, 12
      Major Program Goals FY 2004 – 2008, 13
      Blanco 4-m Telescope, 13
      SOAR 4-m Telescope, 13
      Consortium Operation of the Small Telescopes, 13
      Instrumentation Development for the 4-m Telescopes, 14
   Kitt Peak National Observatory, 14
      Major Program Goals FY 2004 – 2008, 14
      Mayall 4-m Telescope, 14
      WIYN 3.5-m Telescope, 15
      KPNO 2.1-m and Smaller Telescopes, 15
      Instrumentation Development, 15
   Telescope System Instrumentation Program (TSIP) and the Integrated Observing System, 16
      Major Program Goals FY 2004 – 2008, 16
      Major Program Activities, 18
   Adaptive Optics Development Program 18
      Major Program Goals FY 2004 – 2008, 18
      Major Program Activities, 18
3. IMPLEMENTING THE DECADAL SURVEY ................................................................. 19
   Giant Segmented Mirror Telescope (GSMT), 19
   Science with a 30-m GSMT, 19
   Next Steps: A Public-Private Partnership to Advance the GSMT, 20
   AURA Proposal to the NSF, 21
   Major Program Goals FY 2004 – 2008, 21
   The Large-aperture Synoptic Survey Telescope (LSST), 22
   Major Program Goals FY 2004 – 2008, 22
   LSST Design and Development, 23
   Data Products Program, 24
   Major Program Goals FY 2004 – 2008, 25

4. MAJOR INSTRUMENTATION PROGRAM ................................................................... 27
   Overall Program Objectives, 27
   Major Program Goals FY 2004 – 2008, 27
   Description of Major Work Packages, 27
   Program Components, 32
   Project Phases and Resources, 33

5. SCIENCE EDUCATION AND PUBLIC OUTREACH ............................................... 34
   Mission and Objectives, 34
   Major Program Goals FY 2004 – 2008, 34
   Science Education, 34
   Public Outreach, 36
   Major Program Activities FY 2004 – 2008, 36
   Science Education, 36
   Public Outreach, 49
   Media Outreach and Public Information, 41

6. MANAGEMENT AND BUDGET ................................................................................... 43
   Management Structure and Organizational Chart, 43
   Level 2 Budget Tables FY 2004-2008, 44

7. PERFORMANCE INDICATORS AND METRICS ................................................... 52
   Public Access and Observing Support, 52
   Public/Private Partnerships and Collaborations, 55
   Public Access to the Gemini Telescopes and the Telescopes of the Independent Observatories, 56
   Analyzing, Archiving, and Disseminating Astronomical Data, 56
   Leadership in Development of New Telescopes, Instruments, and Techniques, 57
   Building the Integrated Ground-Based/OIR System of Public/Private Telescopes, 57
   Support of Scientific Staff Who Conduct Research for its Intrinsic Value, 58
   Astronomy Education and Training Programs, 61
EXECUTIVE SUMMARY

Fast forward to 2008, and we see NOAO engaged in building two large, but very different, telescopes, the vanguard of a revolution in optical/infrared astronomy foreseen in the decadal survey *Astronomy and Astrophysics in the New Millennium*.

Three major advances in technology are completely rearranging the landscape in OIR observational astronomy. We have finally surpassed:

- *Galileo in optics*: because ground-based telescopes can be diffraction limited, and performance gains can go like telescope diameter to the fourth power;
- *Amateur astronomy* in real time field of view, and
- *Kodak* in information storage.

*When we have the digital sky on disk, the virtual observatory will render many labor-intensive observational programs data mining tasks, no longer the province of observers in cold domes.*

The decadal survey’s realization of the diffraction-limited large-aperture telescope is the Giant Segmented Mirror Telescope (GSMT). The years 2004-2008 find this observatory in its design and development phase. NOAO is a partner in developing one of the concepts for GSMT, and is more loosely connected to another concept, the Giant Magellan Telescope (GMT). NOAO is administering for NSF the Adaptive Optics Development Program (AODP), providing the key new technology for GSMT.

The realization of the all-sky survey, opening the time domain for astronomy, is the Large Synoptic Survey Telescope (LSST). In 2007 we expect to see this project emerge from its design and development phase, and move into construction. Again, there are two current concepts for LSST, each with a 3 degree field of view, one with a single large aperture, the other with multiple small apertures.

To serve these two new facilities, which are expected to be built by privately-led partnerships, NOAO is expanding both its major instrumentation and its data management programs. The major instrumentation program is currently partnering with universities to help provide the second generation of instruments to the Gemini Observatory, and will subsequently extend this approach to the GSMT. The data management program will provide the community interface to databases supplied by the Mayall and Blanco telescope wide fields, the PanSTARRS precursor to LSST, and finally the LSST itself.

OIR community strategic planning is a vital element of NOAO’s 2004-2008 program. Consolidation is an essential part of such an aggressive plan for new facilities. Processes, tested in 2001-2003, will be used to achieve this consolidation. These include the Telescope System Instrumentation Program (TSIP), instrumentation partnerships and consortia, such as the Small Medium Aperture Research Telescope System (SMARTS), which passed its first review in 2003.
1 A SCIENCE DRIVEN PROGRAM

WHERE WE ARE TODAY

The past decade has witnessed dramatic discoveries, surprises, and advances in our understanding of the universe. For example:

- Observation of large samples of supernovae in galaxies out to redshifts $z \sim 1$, which provide compelling evidence of dark energy consistent with the inferences from microwave background observations.

- The first observations that quantify fluctuations in the microwave background over a wide range of angular scales. These observations provide both essential independent constraints on fundamental cosmological parameters, and empirical “initial conditions” for modeling the evolution of large-scale structure and the emergence of galaxies.

- Discovery of super-massive black holes hosted in a large number of galactic nuclei, the mass of which is tightly related to the galaxy stellar velocity dispersion. This result argues not only that black holes are a fundamental component of all galaxies including our own, but that the formation of the black holes and the galaxies themselves are deeply intertwined.

- Discovery of gamma-ray bursters and their optical counterparts via observations with space and ground-based telescopes, resulting in the unambiguous association of these incredibly energetic events with extragalactic systems.

- Discovery of dark matter in aggregates of size and mass comparable to galaxy clusters—but apparently not associated with visible clusters—via statistical studies of the effects of gravitational lensing on the isophotal contours of distant galaxies.

- Detection of large numbers of forming and mature sub-stellar mass objects via photometric and spectroscopic studies of young stellar clusters, and deep optical and infrared imaging and astrometric studies of low luminosity stars in the solar neighborhood. These objects span masses from a few tens of Jupiter masses to the hydrogen-burning limit and are beginning to provide important insight into the chemical and physical processes that control the structure of planetary mass objects.

- Detection of large numbers of Jovian mass extra-solar planets, the vast majority located at distances within an astronomical unit of their parent star. This surprising result has led to a proliferation of new theories of planet formation and migration, and called into question whether Earth-like planets located in habitable zones are a common outcome of the solar system formation process.

These advances represent not only the fruits of the collective efforts of teams of astronomers, but the culmination of investments in a wide variety of observational tools, ranging from ground-based imaging surveys with moderate-aperture telescopes (2MASS, SDSS, CCD mosaic cameras on 4-m class telescopes), through spectroscopy with the Keck and Gemini telescopes, to a variety of space-based and balloon assets, including both Explorers (e.g., WMAP) and Great Observatories (e.g., HST and Spitzer). Ground-based O/IR astronomy played a paramount role in
these discoveries. As we look ahead, NOAO must be prepared to support these advances by offering the facilities necessary to the U.S. astronomical community.

THE NEXT DECADE

As we look ahead to the next decade, astronomers stand poised to research such fundamental questions as:

• How the largest structures of the universe take form and evolve, how they relate to the initial conditions imprinted at the time of the Big Bang, and how the cosmological system that governs the universe orchestrates these events.

• How galaxies form and evolve from local density fluctuations to pre-galactic entities—through mergers to mature galaxies—and how these processes are affected by environment.

• How and when black holes form, and how galactic nuclei evolve.

• How stars and planetary systems emerge from molecular clouds and pre-stellar cores; what physical, chemical, and environmental conditions determine the spectrum of stellar masses, how individual stars evolve, and whether the emergent distribution of planetary architectures favors formation of large numbers of habitable planets, or whether Earth represents a cosmic accident.

Answering these questions will require combining results both from extant ground- and space-based facilities, which will provide enabling surveys and pathfinder observations, and from new facilities (e.g., JWST, FIRST, ALMA, LSST, and GSMT), which will provide the advances in sensitivity, angular resolution, and angular coverage crucial to enabling broad-scale progress.

Major Objectives FY 2004 – 2008

The major objectives for the present planning period are underscored in the current Cooperative Agreement with the National Science Foundation:

➢ To support research with the Gemini Observatory through the NOAO Gemini Science Center (NGSC)

➢ To enhance state-of-the art science facilities at Kitt Peak National Observatory (KPNO) and Cerro Tololo Inter-American Observatory (CTIO)

➢ To lead community-based planning, design, and development efforts for proposed federally-funded initiatives in ground-based optical/infrared (O/IR) astronomy, the Large-aperture Synoptic Survey Telescope (LSST), and the Giant Segmented Mirror Telescope (GSMT)

➢ To develop the means to archive ground-based data for the National Virtual Observatory (NVO)

➢ To build a robust capability to design and construct new instrumentation, and to increase the productivity of existing telescopes, while meeting the challenges of the next-generation facilities
To foster the development of an integrated national observing “system” through the Telescope System Instrumentation Program (TSIP)

To integrate education and outreach with research in all of these areas

**LSST and GSMT**

The LSST and GSMT, the new ground-based O/IR facilities recommended by the AASC, will play a key role in addressing these questions. The LSST represents an unprecedented advance in opening the time domain. NOAO has joined a partnership—initially formed from the Universities of Arizona and Washington, Research Corporation, and AURA—to develop the survey telescope system; its centerpiece is the 8-m primary mirror design pioneered by Roger Angel of Steward Observatory and fine-tuned by Lynn Seppala of Lawrence Livermore National Laboratory. Other DOE Labs are planning to design and build a Gigapixel camera. Funding permitting, this LSST system could go into operation as early as 2011. A mission on a faster track is the University of Hawaii’s Pan-STARRS project, with first light in 2006. NOAO plans to collaborate with UH on data management in order to provide value-added data products for the community. The science mission for the LSST has been studied in detail by the LSST science working group, chaired by Michael Strauss of Princeton University.

The GSMT will be a larger scientific advance in 2015 over its predecessors than the Keck telescope was in 1992. This is already apparent from the extraordinary potential of adaptive optics, the heart of the GSMT. The GSMT science working group, chaired by Rolf Kudritzki of UH, is exploring these matters in depth. For the design and development of a thirty-meter telescope concept (TMT), NOAO, in collaboration with Gemini under the auspices of the AURA New Initiatives Office (NIO), is partnering with Caltech, the University of California, and the Association of Canadian Universities for Research in Astronomy. The goal is a detailed design ready for contracting in 2008. Both the GSMT and LSST were conceived by the AASC as public-private partnerships. A fast timeline for these projects is dependent on private fundraising.

**Data Products Program (DPP)**

The GSMT will be the driver of spectroscopic understanding for the James Webb Space Telescope (JWST) and the Atacama Large Millimeter Array (ALMA). The experimental approaches needed will in most cases demand large, often panchromatic databases—in some cases, petabytes in scale—from which samples spanning the requisite ranges of physical, chemical, and environmental conditions must be drawn and analyzed. The sheer scale of these databases will require qualitatively new approaches to data management and analysis, as well as extensive numerical modeling that exploits the full power of modern, parallel, teraflop computing. Moreover, the scale of the problems will require development of innovative ideas and approaches by individual scientists, and coordination of teams of researchers—at planning and carrying out large campaigns making use of a suite of ground- and space-based facilities—on scales unprecedented in astronomy.

**KPNO, CTIO, and Gemini**

Our current telescopes support the scientific themes articulated in the AASC decadal survey. “Red envelope” galaxies from O/IR surveys can trace the development of large-scale structures
through intermediate to high redshifts. CCD Mosaic imagers can provide initial detection of distant supernovae, followed by light curves from Gemini and the Hubble Space Telescope (HST). Gravitational lens mass tomography and mapping of the Kuiper Belt will continue with systematic surveys. Candidates for the “Dawn of the Modern Universe” at $z > 5$ will be culled from $R$-band dropout surveys with the Mosaics and in the near-IR. The attack on star and planetary system formation will be intense, with near-IR imaging and multi-object spectroscopy of star-forming regions as a complement to Spitzer Space Telescope and radio studies. Wide-field CCD monitoring will be employed to investigate the census of planetary transits for large samples of stars. The aspects of depth and time domain highlight the ongoing need for systematic surveys that surpass the coverage of the 2MASS and Sloan Digital Sky surveys. Such surveys also will serve as critical precursors to the all-sky monitoring of the LSST.

**Major Instrumentation Program**

Astronomical instrumentation is in a period of rapid change. By the end of this Long Range Plan period, NOAO will be designing instrumentation for a 30-m telescope. We enter the period having successfully delivered a $5M facility infrared spectrograph for the Gemini Observatory, and carrying out feasibility and design studies for the “Aspen” generation of instruments. Along the way, we have the challenge of major instruments for the 4-m telescopes, the Mayall and Blanco (which will share a 30 arcmin infrared imager); the WIYN, which is developing a one-degree optical imager; and SOAR, which aspires to develop adaptive optics at optical wavelengths.

Technological change continues to favor O/IR astronomy. The new facilities advocated by the AASC lead us to anticipate with confidence that we can enter the reionization epoch in the coming decade to learn more of the era of galaxy formation. Resolution and distance limits continue to be pressed back. Productivity continues to grow in photometry and spectroscopy—illustrated by the proposed Kilo Aperture Optical Spectrograph (KAOS). High resolution spectroscopy continues to make strides, as chemical composition analysis becomes possible for progressively fainter stars, and velocity precision homes in on its goal of detecting terrestrial planets. An essential element of NOAO’s science plan is to exploit this Moore’s Law-like behavior of ground-based O/IR astronomy by pursuing the science enabled by technological advances.

**Public Affairs and Educational Outreach (PAEO)**

New astronomical facilities of the scale and productivity we are planning place special responsibilities on NOAO public affairs, and offer great opportunities for education and outreach. The growth of PAEO will continue over the planning period with particular emphasis on (1) the role of GSMT and LSST in science education and (2) development of the Kitt Peak Visitor Center to meet the rapidly advancing expectations of visitors and residents alike in the Southwest.

The major program objectives described above are developed in detail in the following sections of this plan: The National Observing System, Implementing the Decadal Survey, Major Instrumentation, and Science Education and Public Outreach. Management, budget, and performance metrics are described in the final two sections. A consistent theme of NOAO’s approach in this Long Range Plan is partnership with universities and independent observatories.
Observing the distant universe

Improving resolution from the ground

Productivity and the multiplex advantage

High resolution spectroscopy

Figure 1. Four plots showing the increasing power of O/IR ground-based capabilities represented by NOAO instrumentation as measured by various performance metrics. The top left plot shows the increase in the largest redshift known for galaxies and QSOS with time. The top right plot shows the gain in spatial resolution of ground-based observations. The bottom left plot demonstrates the increase in productivity through several measures. The bottom right plot shows the gain in precision and limiting magnitude of high resolution spectroscopic observations.
THE NOAO SCIENTIFIC STAFF

Major Program Goals FY 2004 – 2008

- Intellectual leadership for each of NOAO’s programs from a team of both experienced and early-career astronomers
- Measurable, rising research productivity
- A supportive environment for research with exemplary diversity and equity

NOAO is a scientific research organization whose mission is to enable research and discovery by a broad community of scientists, and to communicate widely with its various constituencies in the community. The heart of any research organization is its staff of researchers. Indeed, NOAO’s scientific staff sets the overall standards for the institution. These standards include the quality and state-of-the-art nature of the research facilities, their relevance to the key research questions of today and tomorrow, the research ethos of the institution, the match to university research culture and educational goals, and the ability of NOAO as an institution to innovate, to work with the community to plan for the future, and to anticipate user needs.

To recruit and retain a scientific staff able to fulfill the multiple roles of (1) scientific excellence, (2) commitment to institutional and community goals, and (3) leadership in the community is a challenge; it requires an observatory culture that encourages all three. Essential to this culture is a stimulating scientific environment within NOAO, along with time required to carry out first-rate scientific programs. Our staff members are thus granted 50 percent research time. Also critical is a commitment to institutional service and community leadership—roles analogous to the teaching and service missions at peer university institutions. This 50/50 split between research and service, 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.

Standards for tenure and post-tenure review are matched to the vision of excellence in science, service, and leadership, and are maintained at the level of major research universities. NOAO’s internal tenure committee also acknowledges innovation as an additional criterion for tenure—thus emphasizing the importance of continuous improvement of NOAO’s research facilities. The application of these standards in service of NOAO’s institutional roles is closely monitored by AURA’s Observatories Council and Board of Directors.

In addition to the professional respect of colleagues, NOAO’s mission requires that its scientific staff play a leadership role in the community, especially in the service of advancing community aspirations. Academic or research leadership is, of course, a subtle blend of forward thinking, effective communication, and the ability to see advancement of community goals as central. Recent demonstrations of community leadership by NOAO staff include: (1) successful launching of the Telescope System Instrumentation Program (TSIP) and the Adaptive Optics Development Program (AODP); (2) development and implementation of programs to enable planning of joint ground- and space-based observing programs with SST, Chandra, and HST; (3) 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; and (4) continuing support of science working groups for the GSMT and LSST projects.
The Changing Staff at NOAO

The recent challenges of launching the Data Products Program (and its link to the National Virtual Observatory), the NOAO Gemini Science Center (NGSC), and the LSST and GSMT programs have required the current NOAO staff to play multiple roles: ensuring the continued successful operation of KPNO and CTIO facilities, while providing smooth access to Gemini, and planning new generation facilities and capabilities. NOAO’s ability to meet these challenges over the long run requires investment in new staff. Early in the planning period, we expect to add up to five new staff members, and as the DPP, LSST, and GSMT grow, additional staff will be needed. Most will be young researchers whose imagination and commitment will be critical to achieving NOAO’s and the community’s long-term aspirations. Their arrival at NOAO North and NOAO South will provide a noticeable level of excitement as their enthusiasm diffuses through Tucson and La Serena staff offices.

Performance Metrics

Evaluating and enhancing staff performance in research, service, and leadership require regular communication and measurement against clearly understood metrics. NOAO carries out annual performance reviews during which staff members and the associate directors of their “home” programs meet and review professional accomplishments and goals, and determine how well they are being met by the individual and how well the observatory is doing in providing the environment and resources to enable success. In addition, NOAO has established more formal metrics of staff performance, which we intend to use as a key part of promotion, tenure, post-tenure review, merit raises, and internal awards. These are described in the final management chapter of this plan.

Mentoring

Mentoring the large number of new staff, along with our post-doctoral fellows, is essential to ensuring their continued research productivity, their commitment to NOAO and community goals, and their personal growth. NOAO management has developed a systematic program of mentoring for scientists at all levels, but particularly for young staff and post-docs. As a new program, this will require test and assessment. The Associate Director for Science also works with the staff during the annual staff retreat to discuss and plan major research programs coherently.

Women Scientists at NOAO

Adding significant numbers of new staff at NOAO provides an opportunity to proactively recruit outstanding women. Success will enable a welcome increase in the diversity of the staff, which in itself will enhance the environment for women. Among the measures we are adopting to attract women to NOAO is to provide opportunities for both spouses in two-career families—critical at both NOAO North and NOAO South, but especially in La Serena.
The ability to attract and retain first-rate female scientists requires, above all, a challenging and exciting environment, and one that is conducive to listening carefully and responding to both men and women. Our annual scientific staff retreats provide an excellent forum for open discussion of the work environment and communication issues at NOAO, and can serve as an early warning to management of problems hiding just below the surface.

NOAO South postdocs, from left to right: James de Buizer, Armin Rest, Dara Norman, Marcel Bergmann, Sean Points
2 THE NATIONAL OBSERVING SYSTEM

NOAO GEMINI SCIENCE CENTER (NGSC)

Major Program Goals FY 2004 - 2008

The twin 8-m Gemini telescopes form the apex of the facilities that NOAO offers to the U.S. astronomical community. Gemini has particular competitive advantages in the infrared, in delivered image quality, and in adaptive optics. The goals of the NOAO Gemini Science Center (NGSC) are to:

- Meet U.S. community needs for 8-m aperture telescopes
- Provide user support to the U.S. users of Gemini
- Develop the input from the U.S. partner perspective to Gemini Observatory in science planning, instrument development, and operations support
- Perform community outreach on Gemini opportunities to the U.S. community

NOAO and the NGSC bring to the Gemini partnership a long history of broad community involvement in the scientific planning and operations of national observatory facilities, including extensive community participation in the NOAO telescope time allocation process. NOAO also offers a wide range of in-house scientific expertise that encompasses the Gemini science goals and instrumentation diversity. The NOAO instrumentation program offers valuable technical expertise to the Gemini Observatory. The co-location of NGSC and Gemini staff in La Serena, Chile presents extensive opportunities for collaboration.

Science Direction

Within the structure of the Gemini partnership, each partner agency created a national office to represent its participation in Gemini. The Gemini offices form the nodes of communication between Gemini and each partner country, providing input and advice to Gemini Observatory on partner perspectives and communicating to the national communities the capabilities and science opportunities that Gemini presents. NOAO is the home of the U.S. national Gemini office, and the director of the NGSC is the U.S. Gemini scientist.

In order to access and represent U.S. interests, the NGSC director is assisted by a science advisory committee (U.S. Gemini SAC) that consists of eight to ten prominent members of the U.S. astronomical community. This committee meets annually to advise on science direction, operations models, instrumentation issues, and the full variety of Gemini matters. Frequent telephone conferences and e-mail updates and exchanges allow the perspectives of a broad range of science expertise and interests to form the consensus and to provide advice to the NGSC director. Six members from the U.S. SAC are selected to attend the annual international Gemini Science Committee meetings.
User Support

User support at the NGSC is the responsibility of a group of a dozen instrument scientists—ranging from quarter-time to nearly full-time—whose areas of scientific and technical expertise are matched to the diversity of Gemini instrumentation. The instrument scientists assist U.S. investigators in preparing observing proposals, which are then peer reviewed and ranked by the NOAO telescope time allocation committee. The complexity of the Gemini instruments and operations requires complex observing protocols and calibration observations. Proposers who are granted Gemini time are required to submit a Phase II observing proposal. NGSC instrument scientists assist U.S. community members in preparing these proposals using the Gemini Observing Tool, and then NGSC staff check these Phase II submissions before passing them on to Gemini for execution.

A remote operations center has been established in Tucson with high-speed Internet connections to the Mauna Kea and Cerro Pachón sites. The remote operations center will serve community observers as well as NGSC staff, enabling staff to support U.S. observers and U.S. instrumentation efforts on Gemini. NGSC staff will also use this center for training and for conducting engineering programs.

In order to attain Gemini science goals, data reduction, pipelining, and analysis tasks must be developed for Gemini data. NOAO and the Gemini Observatory are now several months into a collaborative project with the (appropriately) twin goals of improving both the Gemini reduction software and the underlying IRAF system it uses. The key to success in this case is that the partners are not only dedicating new resources to the project, but also the expertise and institutional commitment required to meet its goals—a combined 70 person-years of IRAF development experience from NOAO, detailed knowledge of the instruments and reduction requirements from Gemini staff, and shared responsibility for development and scientific oversight of the project.

Operations Support

NGSC staff provide support for the commissioning and system verification of U.S. instrumentation. NGSC staff are also responsible for operations support of shared Gemini instruments from the United States, currently Phoenix (an NOAO-provided high-resolution infrared spectrograph shared between Gemini South and SOAR). NGSC staff participate in the testing, maintenance, and calibration of these shared instruments, and provide documentation on performance, operation modes, and calibration procedures for the Gemini community.

Instrumentation Development

As the major partner in Gemini, the United States contributes approximately half of the major Gemini instrumentation. It is the role of NOAO and the NGSC to foster instrumentation development for Gemini in the U.S. community. This effort is divided between projects undertaken directly by NOAO (e.g., GNIRS) and projects under development elsewhere in the U.S. community (e.g., NIRI, T-ReCS, NICI, FLAMINGOS-2), in collaboration with university groups (thus far, the University of Florida and the University of Hawaii) and corporations (currently, Mauna Kea Infrared). The NGSC fulfills this role through a range of activities, including:
• Encouraging responses to Gemini instrument procurement opportunities by circulating announcements widely, and organizing workshops and facilitating collaborations where appropriate

• Facilitating the instrument review process (conceptual, preliminary, and critical design reviews; NGSC quarterly reviews)

• Publicizing progress on instrument development within the U.S. community

• Making the NOAO Flexure Test Facility available to realistically test instrument performance prior to on-telescope testing

The Gemini partnership began a process in early 2002 to identify the major science opportunities for Gemini in the period 2008–2012 and the instrumentation required for Gemini to capitalize on these opportunities. This process included community-based workshops in the Gemini partner countries. NGSC organized a workshop for the US community, “Future Instrumentation for the Gemini 8-m Telescopes: US Perspective in 2003,” on 30–31 May 2003 in Tempe, Arizona (report available at www.noao.edu/usgp/Tempe_Report_7-8.pdf). Gemini then conducted an international science and instrumentation planning meeting in Aspen, Colorado, on 27–28 June 2003. It is the instrument concepts arising from this process that NGSC is working to enable, in collaboration with the U.S. community.

Building the Gemini Community

The NGSC communicates with the user community by means of articles in the NOAO/NSO Newsletter; special brochures; “town meetings;” NGSC booths and special sessions at AAS meetings; electronic announcements; and Web-based information. NGSC has initiated the use of Webcasts to inform the users on specific Gemini issues (thus far, the Call for Proposals for semester 2004A, and also the availability of GNIRS in semester 2004B).

The NGSC intends to organize and conduct science workshops, in collaboration with Gemini and other national Gemini offices, to highlight particular areas of Gemini science that are both timely and productive. NGSC is currently collaborating with Gemini and the other National Gemini Offices to organize the “Gemini Science 2004” meeting in Vancouver in May 2004. This meeting will provide a showcase for Gemini science results, and Taft Armandroff is the Chair of this meeting’s Scientific Organizing Committee. Currently anticipated topics for future workshops are “Astrophysics in the Mid-IR with Gemini” or “New Frontiers in Coronography.” The NGSC also will sponsor technical workshops—like our previous workshop on AO data reduction—to assist the community in obtaining the highest scientific return from Gemini observations. T-ReCS and/or GNIRS data reduction workshops are envisioned. Future workshops may focus on multiple object spectroscopy in the optical and near-IR (with GMOS and FLAMINGOS-2), on integral field spectroscopy, or on other specialized analysis tools and procedures.

To mark the launch of the NGSC, a new post-doctoral program was created to encourage young astronomers to utilize the Gemini telescopes for innovative science. This program complements AURA’s U.S. Gemini Fellowships for post-graduate study in the United States by members of the South American Gemini community.
CERRO-TOLOLO INTER-AMERICAN OBSERVATORY

The telescopes offered at CTIO – Blanco, SOAR and several smaller instruments—provide US astronomers with a wide variety of state-of-the-art facilities, which they can use to study the southern skies in great detail. As such they form a vital part of the suite of capabilities available in the national system. The Blanco 4-m telescope offers wide-field capabilities; the SOAR 4-m telescope will have several very efficient narrow-field instruments, those working in the optical bandpass are blue-optimized so as to complement the IR-optimized Gemini 8-m. The smaller telescopes provide a wide range of opportunities, from synoptic and target-of-opportunity programs to large-scale surveys. Additionally, CTIO provides the infrastructural and engineering support that allows the efficient implementation of projects ranging from short-term experiments to major new facilities, at one of the world’s best observing sites.

Major Program Goals FY 2004 – 2008

Blanco 4-m Telescope

- Operate with a fixed complement of wide-field instrumentation: the Mosaic 8K CCD imager, the ISPI 2K IR imager, and the Hydra multi-object wide-field spectrometer. Older facility instruments such as the RC spectrograph and the Echelle spectrograph will be retired as superior Gemini instruments and the SOAR echelle come on-line.

- Upgrade the wide-field IR imaging capability in 2006 by sharing NEWFIRM with the KPNO Mayall, on a 6-9 month cadence.

- With a partner, provide a major new instrument capability in 2008.

- Upgrade the telescope control system in 2005-2006, and optimize the telescope performance so the new instrumentation can be efficiently utilized.

SOAR 4-m Telescope

- Commission the SOAR telescope and its initial instrument complement in 2004; begin scheduled operations in 2005.

- Support and optimize use of the NOAO-provided instruments: the SOAR optical imager, built at CTIO, the IR imaging spectrometer OSIRIS, which is provided in a partnership with Ohio State University, and the high resolution IR spectrograph Phoenix, which will be shared between SOAR and Gemini.

- Participate in the plans by the other SOAR partners (Brazil, University of North Carolina, Michigan State University) to enhance the basic operations provided by CTIO by developing efficient queue observing in a multi-instrument environment.

Consortium Operation of the Small Telescopes

- Continue operation of the small telescopes as part of the Small and Moderate Aperture Telescope Research System (SMARTS) consortium which began operating the CTIO 1.5-m, 1.3-m, and 0.9-m telescopes in 2003 for an initial period of three years.
- Participate in the commissioning of a 4K CCD imager, built by consortium member Ohio State University, on the 1.0-m Yale telescope, and in the installation of the 2K wide-field IR Imager CPAPIR (U. Montreal–AMNH). Both these activities will take place in 2004.

- Extend the present three-year agreement when it finishes at the end of 2005. Bring the Bochum 1.5-m telescope, to be installed on Cerro Tololo in late 2004, into the range of facilities offered.

**Instrumentation Development for the 4-m Telescopes**

The present Blanco instrumentation (Hydra, Mosaic, ISPI) was built either at CTIO or via a partnership with NOAO Tucson. Further development of the Blanco in the context of the U.S. system of telescopes—and new facilities now in planning—involves a substantial enhancement of its wide-field capabilities. It is planned to share the NOAO Extremely Wide-Field Imager (NEWFIRM), a 4K IR imager now being built at NOAO Tucson, between the Blanco and Mayall telescopes. A new instrument partnership is being actively solicited in 2004. An attractive option would be to build new prime focus optics and a very large CCD mosaic to cover a field of more than two degrees square. Such an instrument would be a major undertaking; steps are underway to identify a partner who would share its construction in exchange for a substantial amount of observing time spread over several years.

CTIO has built the SOAR optical imager, focal plane assemblies, and dewars for the optical instruments, and substantial parts of the SOAR instrument infrastructure. As part of NOAO’s obligation to SOAR, CTIO is building an adaptive optics facility (SOAR Adaptive Module, SAM), under the aegis of the NOAO Major Instrumentation Program. The instrument, now approaching Preliminary Design Review, will provide a wide field with improved and constant image quality by using a Raleigh laser beacon to compensate for ground layer turbulence. These techniques are relevant to developments needed for the next generation of extremely large telescopes.

**KITT PEAK NATIONAL OBSERVATORY**

KPNO is a key component in the integrated system of U.S. ground-based O/IR telescopes. The wide-field capabilities of the Mayall and WIYN telescopes provide essential support for the major portion of the U.S. investment in large glass, with six out of the eight independent large-aperture telescopes in the northern hemisphere. Observing programs and survey data sets from the Mayall and WIYN telescopes create a level playing field for effective utilization of Gemini North. These NOAO telescopes greatly enhance the exploitation of national space assets by providing optical/near-IR source identification, reconnaissance spectroscopy, and synoptic monitoring. KPNO data are of particular value to those multi-wavelength programs that rely on VLA and EVLA observations.

**Major Program Goals FY 2004 – 2008**

*Mayall 4-m Telescope*

- Operations with high reliability and demand-driven suite of competitive instrumentation
- Integration of active optics and thermal controls into an effective system with consistent subarcsecond delivered image quality
Commissioning and operations of STScI/GSFC/KPNO IR Multi-Object Spectrograph, starting in early FY05

Commissioning and operations of NEWFIRM, the 4K × 4K Near-IR Extremely Wide-Field Imager, starting in late FY05. The instrument will be shared with CTIO on a cadence to be decided.

Successful continuation and renewal of the instrumentation partnership with the University of Maryland astronomy department, including development and operation of NEWFIRM pipeline

**WIYN 3.5-m Telescope**

- High-efficiency operation with maintenance of excellent image quality over the full wide-field
- Strong NOAO participation in design, fabrication, commissioning, and operation of the One-Degree Imager (ODI) with orthogonal-transfer CCDs, with operations in 2008
- Enhanced wide-field spectroscopy, including increased throughput, updated positioning, precision radial velocity modes, and other consortium-driven improvements; initial improvements in FY05.
- Full exploitation of the WIYN tip/tilt module, including extension to near-IR imaging

**KPNO 2.1-m and Smaller Telescopes**

- Low-cost operations of the 2.1-m to support wide-field IR imaging and multi-object spectroscopy, as well as demand-driven optical imaging and spectroscopy
- Reassessment of 2.1-m status at the time of NEWFIRM science operations, with probable operations partnership
- Continued KPNO proposer observing with CCD Mosaic on the WIYN 0.9-m

**Instrumentation Development**

To support the survey and synoptic capabilities characterizing its unique role in the national system, NOAO must provide a powerful suite of wide-field instruments, operated at low cost, with scheduling and operational modes enabling the production of large, uniform data sets accessible to the astronomy community. The strongest science can emerge from a mix of surveying and some traditional PI observing.

KPNO will offer the wide-field Mayall 4-m and WIYN 3.5-m telescopes on a very good continental site. The modern design of WIYN allows it to deliver a median FWHM < 0.8” in R, consistent with the recent site test value of < 0.7”. WIYN image quality monitoring records FWHM 0.57” for 22 percent of the time. The program of refurbishment of the Mayall 4-m is complete at the hardware level. This includes dome ventilation, mirror chilling and air flow control, active support of the primary mirror, wavefront sensing, and secondary focus and tilt.
control. Integration at the system level is now the priority. CCD Mosaic users report stacking hours of integrations and maintaining 0.8” image quality.

The instrument complement will evolve from versatility toward dedication to wide-field image surveying, particularly on the 4-m telescopes. Currently the Mayall is equipped with the Prime Focus CCD Mosaic Imager with 8K × 8K format covering 37’ square; the FLAMINGOS wide-field near-IR imager and cooled multi-slit spectrograph, developed in partnership with the late Richard Elston at the University of Florida; the Simultaneous Quad Infrared Imaging Device (SQIID), the four-color near-IR imager; and optical spectroscopic capability with emphasis on high efficiency in the far red. WIYN provides the Hydra multi-fiber positioner plus bench spectrograph covering one degree; the direct imager, Mini-Mosaic; and the Tip/Tilt imager with rapid guiding correction, all mounted simultaneously and addressable with the rotatable tertiary. Because it can accommodate the 4-m near-IR instrumentation, the 2.1-m will continue to be operated, but with minimal technical support. The combination of the 2.1-m plus FLAMINGOS does provide a 20’ field of view (FOV) in the near-IR, making it a powerful survey capability in the near term.

Three major new instruments are planned. NEWFIRM will be a wide-field near-IR imager with a 4K × 4K mosaic array detector, covering a 30’ square FOV on the 4-m, planned for delivery in 2005. The Goddard Space Flight Center and the Space Telescope Science Institute are building a prototype multi-object near-IR spectrograph with a micro-mirror array as a programmable slit mask, now scheduled for first light commissioning in July 2004. When NEWFIRM and the Goddard IRMOS are fully commissioned, SQIID will be retired and the 2.1-m opened to operations partnership, with the goal of continuing operations in a single optimized configuration. The WIYN consortium is actively pursuing the development of a one-degree CCD imager with orthogonal-transfer integrated CCD arrays for local fast guiding. The goal is scientific operation in 2008.

TELESCOPE SYSTEM INSTRUMENTATION PROGRAM (TSIP) AND THE INTEGRATED GROUND-BASED/OIR OBSERVING SYSTEM

Major Program Goal FY 2004 – 2008:

- Strategic development by the community of the U.S. national system

The McKee-Taylor decadal survey developed the concept of a system of private- and publicly-funded ground-based O/IR telescopes as a context for understanding the needs of the research community and addressing those needs. This context provides the basis for the emphasis on partnerships with the community for much of the NOAO program. In addition, several activities within the program are motivated by the desire to strengthen this system and make it effective. These include the administration of the Telescope System Instrumentation Program (TSIP) and the activities of the newly-established Committee for the Development of an Integrated Ground-Based/OIR System (CDIS).

The highest priority medium-sized initiative of the decadal survey is the TSIP. This NSF-funded program is aimed at channeling new resources to providers of needed capabilities to enhance the system of ground-based O/IR facilities. TSIP, through a peer-review proposal process, funds the development of facility-class instruments for the telescopes of the independent observatories and provides time on these telescopes to the community, thus simultaneously improving the capabilities within the system and broadening access to its elements. NOAO administers this program—providing management of the selection process, as well as contract management—to
ensure that the federal funds are used effectively and efficiently to provide the capabilities that the community has identified. In addition, the distribution of telescope time from TSIP contracts is integrated into NOAO’s semi-annual telescope time allocation process.

TSIP began in FY 2002 with annual funding allocations of $4M in the first three years; we expect that the funding will rise to the $5M-per-year level recommended by the AASC report. As a result of the first year of activity, two new Keck instruments are under development—one in fabrication and one in design—and 41 nights on the Keck telescopes have been made available to the community. The review of proposals in the second year resulted in a new instrument for the MMT and Magellan telescopes, 27 nights at each of the MMT and Magellan observatories, and 12 additional nights on the Keck telescopes. The cycle of solicitation, proposal review, negotiation of contracts, and contract monitoring is expected to repeat each year. Peer review panel membership will change somewhat as conflicts of interest arise, but the intent is to populate the panel with a broad mix of expertise in astronomical instrumentation and understanding of community needs. Administration by NOAO costs TSIP approximately $50,000 per year.

In order to help the system evolve to better address the needs of the community, NOAO also must develop a process for understanding those needs. The ground-based O/IR community currently has no strategic planning process other than its piece of the decadal survey. An important element of the framework of the system is the creation of a mechanism by which the community can develop an evolving plan that identifies needed capabilities and provides ideas for making them available. This plan should be motivated by the scientific aspirations of the community, and also must consider the larger context of using our space-based and other assets most effectively. The strategic plan for the system should guide federal investment, identify contributions that NOAO should make to the system, and create opportunities for the independent observatories.

In undertaking such system framework activities, NOAO must depend on various mechanisms to assemble input from the community and integrate that input into a coherent strategic plan. This should be effected by a group that (1) maintains an overview of the ground-based O/IR system, its needs, and constraints; and (2) is as free from conflicts of interest as possible. To fill that role, we have organized a System Committee that will assist with planning and organizing community meetings and workshops (such as the “First Workshop on the Ground-based O/IR System” held in Scottsdale, Arizona in October 2000), help formulate the discussion into a strategic plan, and advocate that plan to the funding agencies. A second community workshop, “Building the System from the Ground Up” (http://www.noao.edu/meetings/system2), is planned for May 2004 to discuss both evolution of the strategic priorities for the ground-based O/IR system, and the development of system approaches for specific areas such as smaller telescopes, instrumentation, and data archives.

**Major Program Activities**

- *Carry out annual TSIP proposal process.* This activity includes solicitation of proposals, review of the proposals by a peer-review committee, negotiation of sub-awards with the selected proposers, and oversight of the instrument development activity funded by the TSIP sub-award. See: http://www.noao.edu/system/tsip/.

- *Continue strategic planning and development of the ground-based O/IR system.* This is based on the activities of the System Committee, which will conduct community discussions about various aspects of the system and synthesize these into an evolving strategic plan.
ADAPTIVE OPTICS DEVELOPMENT PROGRAM (AODP)

In the decadal survey, the Astronomy and Astrophysics Survey Committee panel on Optical and Infrared Astronomy from the Ground stated that an adaptive optics (AO) effort associated with the development of a Giant Segmented Mirror Telescope (GSMT) should be supported by funding on the order of $5M per year for the next ten years. The panel also noted that AO development work will enhance dramatically the power of existing large telescopes, allowing them to work at the diffraction limit at shorter wavelengths, thereby greatly increasing their scientific power. In 1999, NOAO sponsored a community workshop aimed at developing a road map to guide NSF investment in adaptive optics. Its report was presented to the NSF in mid-2000. In 2003, NSF was able to make available funding in the amount of $3M to support the initial phases of a 10-year AO investment program; in future, the goal is to increase the annual support level to $5M.

NSF requested that NOAO (1) manage the Adaptive Optics Development Program (AODP); and (2) update the road map periodically. In 2003, NOAO issued an Announcement of Opportunity aimed at eliciting proposals responsive to the Adaptive Optics program announcement (http://www.noao.edu/system/aodp/). In fall 2003, 17 proposals were received and evaluated by a panel comprising astronomers, engineers and project managers; six of the proposals were selected for awards. NOAO has completed negotiations with each of the awardees and established a management plan to measure progress against plan.

In April 2004, NOAO will hold a broadly-based community workshop which will provide a summary of ongoing AO activities throughout the world—the context for updating the road map and informing the next Announcement of Opportunity for the AODP.

Major Program Goals FY 2004-2008

- Review proposals received in response to the second Announcement of Opportunity for the AODP
- Successfully manage ongoing and future AODP awards
- Work with the AO steering committee to update the road map and recommend changes in program emphasis to the NSF

Major Program Activities

- Organize AODP annual proposal review
- Negotiate terms and conditions for awards
- Manage awardees
3 IMPLEMENTING THE DECADAL SURVEY

GIANT SEGMENTED MIRROR TELESCOPE (GSMT)

The 2000 decadal survey recommends as its highest ground-based initiative the design of a 30-m Giant Segmented Mirror Telescope early in this decade, and a construction start before 2010. Following this recommendation would ensure completion of the GSMT early in the operations phase of the ALMA and the JWST—thus providing the U.S. community with a next generation telescope that enables full exploitation of these powerful international facilities—and extends the frontiers accessible to current generation 8-10-m telescopes.

In response to the decadal survey’s recommendation, AURA established the New Initiatives Office (NIO) in January 2001. Located in Tucson and involving engineers from both NOAO and Gemini, the primary goals of the NIO are: (1) to build a strong basis for a public-private partnership to design, build, and operate a GSMT; and (2) to develop a comprehensive understanding of key science drivers, instrumentation needs, and telescope design and technology issues. In the longer term, NIO aims to engage international partners in a constructive way that will achieve mutual goals.

Following an 18-month effort involving 11 full-time engineers and scientists and aided by input from multiple community groups, NIO published the results of a major study in the “GSMT Book” ([http://www.aura-nio.noao.edu/book/index.html](http://www.aura-nio.noao.edu/book/index.html)) which developed a point design that established the feasibility of a 30-m class GSMT, identified areas of technical risk, developed a plan for technology development, and established initial cost estimates.

AURA also established the GSMT Science Working Group—a broadly representative community group charged with developing the science case and justification for any federal investment by NSF or other agencies in GSMT. This guidance is intended to be a product of all public, private, and international groups that expect to play a role in the GSMT. The GSMT SWG presented its first report “Frontier Science Enabled by a Giant Segmented Mirror Telescope” to the Astronomy Division of the National Science Foundation July 2003. The report urged timely federal investment in technology development in order to ensure that the Design and Development Phases for ELTs proceed on a schedule consistent with beginning construction of one or more telescopes by the end of the decade.

Science with a 30-m GSMT

The science enabled by the exquisite images that can be delivered by a 30-m diameter telescope is truly remarkable. By concentrating near-infrared light into an image with a core of 0.02 arcsecond size, the GSMT will be able to measure the internal motions, chemical composition, and star-forming activity in the first gravitationally bound star-bearing systems to form following the Big Bang. This would provide the essential tool for analyzing these “building blocks” for the spiral and elliptical galaxies familiar to us today.

The GSMT’s superb imaging quality also will provide the key to resolving the crowded star fields into individual stars in galaxies as far away as 3 Mpc. Analysis of the brightness and color for samples of millions of such stars will reveal the distribution of chemically and chronologically distinct stellar subsystems—the presumed relics of the pre-galactic building blocks that merged together to form galaxies like the Milky Way.
Its power to image fine detail in high contrast scenes and to feed concentrated light from faint sources into powerful spectrographs will enable the GSMT to image and analyze planets and zodiacal dust clouds around hundreds of nearby stars.

The GSMT will yield direct insight into the diversity of architectures characterizing extra-solar planetary systems, the physics and chemistry of extra-solar planetary atmospheres, and the nature of weather on other worlds. For the first time, it will be possible to study a sample of thousands of newborn stars to locate planets in the process of formation, to understand where and when planets of different masses form, and to determine whether planets similar to Earth are likely to survive at distances from their parent suns favorable to the development of life.

At optical wavelengths, the GSMT’s photon-collecting power will enable simultaneous spectroscopic measurements of thousands of galaxies, thereby providing a stereoscopic “image” of how young galaxies and intergalactic gas are distributed in the early universe, and how the large-scale structures defined by these probes are linked to the inhomogeneities (manifest in the cosmic microwave background) built in during the instants following the Big Bang.

The groundbreaking science enabled by the GSMT requires a telescope that (1) delivers extremely high quality (near-diffraction-limited) imaging in the near-IR and wide-field coverage in the visible, and (2) incorporates instruments (cameras and spectrographs) that fully exploit its potential.

**Next Steps: A Public-Private Partnership to Advance the GSMT/TMT**

The decadal survey, and later the GSMT SWG, recommended that design and technology studies for a GSMT begin immediately so that the facility can be completed early in the ALMA and JWST era. Toward that end, in June 2003, AURA signed a Letter of Intent to partner with the California Institute of Technology, the University of California and ACURA to advance the design and development of a 30-m GSMT (the “Thirty Meter Telescope” or TMT)—thus fulfilling the vision of the AASC that the GSMT be realized via a public-private partnership. Indeed, this is a logical extension of the new paradigm for U.S. astronomy—public and private institutions collaborating to provide a “system” of facilities that will ensure continued access by the U.S. community to world-leading capabilities.

The NIO’s role during the three-year Design and Development phase will be:

- To represent the US community during the period in which systems trades critical to ultimate performance will be made, thus ensuring that the resulting TMT design will satisfy broad community aspirations
- To take the lead in evaluating candidate sites for TMT and other ELT projects
- To develop design and simulation tools and carry out technical studies and other activities that benefit all ongoing community efforts to develop new-generation telescopes (e.g., understanding wind-buffeting, developing sophisticated modeling tools for simulating the performance of adaptive optics systems; developing approaches and tools for simulating system performance using “integrated modeling”)
- To provide technical support for the TMT project
AURA’s Proposal to the NSF

In summer 2003, AURA submitted a proposal to the NSF for the funds needed to ensure community participation (through NIO) during the Design and Development Phase of TMT, and also to ensure eventual community access to TMT in proportion to federal investment. In spring 2004, the proposal was revised, and now requests funds from the NSF to invest in the key technologies and design studies needed to advance two concepts for Extremely Large Telescopes (ELTs): (1) TMT and (2) a concept that proposes an alternate technical solution, such as the Giant Magellan Telescope (GMT). Federal investments in the ELT design and technology studies will:

- Enable completion of preliminary designs for TMT and GMT or an alternate concept by the end of 2007. These designs will provide the basis for understanding the performance, cost, and risk of two concepts early enough to enable completion of at least one telescope early in the JWST era—thus meeting the highest priority goal for ground-based astronomy set by the AASC decadal survey.

- Ensure effective and broad community input during telescope design and technical development so that the delivered performance of each telescope concept meets the scientific aspirations of the community. This will be accomplished through a broadly representative Science Working Group (SWG) convened by AURA on behalf of the US community.

- Provide opportunities for merit-based public access to the resulting ELT(s) proportionate to the federal investment during the D&D Phase.

- Engage experienced and skilled groups from throughout the community in the ELT D&D Phases via open competition to carry out key design and technology development tasks and instrument concept studies.

- Support the development of technologies and design tools with utility and applicability for the entire U.S. scientific, engineering, and technological community.

- Evoke significant non-federal funding via (1) an already established partnership among AURA, ACURA, Caltech and the University of California to complete the D&D Phase for TMT; and (2) the requirement of significant private funding for GMT or another complementary ELT design and technology development effort supported by NSF.

- Promote, through AURA’s auspices, open communication between these complementary ELT design efforts in service of accelerating both and preserving the option of a convergence path.

Major Program Goals FY 2004 – 2008

- Develop a science requirements flow-down in collaboration with the TMT Science Advisory Committee

- Provide technical and management support for the GSMT Science Working Group in service of (a) reviewing progress on US ELT efforts and providing community input regarding their science goals; (b) establishing working relationships with ESO’s science planning effort; and (c) developing a quantitative understanding of the complementarity and synergy between GSMT and JWST.
• Provide management and technical support for site evaluation activity in Hawaii, Mexico, and northern Chile

• Develop CFD and integrated modeling tools for analyzing the GSMT and other Extremely Large Telescope (ELT) system concepts

• Develop code for modeling performance of AO systems

• Participate fully and represent the community in the TMT Design and Development Phase (CELT DDP)

• Provide support for other ELT design efforts (consulting re integrated modeling; providing access to AO modeling tools)

• Work with ESO technical groups to align technology investments in service of exploring a wider range of technical approaches and encouraging vendor development on both sides of the Atlantic

• Review progress against plan for ELT program activities that may be supported via the AURA proposal to NSF

Specific goals for FY 2008 and beyond include:

• Successful completion of a proposal to begin construction of an ELT

• Continued representation of the community during the construction, commissioning, and operations phases

• Leadership and coordination of community-based partnerships to build instruments for ELTs

LARGE-APERTURE SYNOPTIC SURVEY TELESCOPE (LSST)

Major Program Goals FY 2004 – 2008

2004:
• Complete proposal to NSF for design and development phase
• Narrow site selection to prime and backup sites
• Freeze optical design
• Complete study of feasibility of secondary fabrication

2005:
• Conceptual Design Review
• Complete construction proposal

2006:
• Test data pipeline prototype
• Select Array Type
• Issue mount request for proposal

2007:
• Conduct PDR
• Begin site construction

2008:
• Conduct Critical Design Reviews for subsystems and for total project
The Large-aperture Synoptic Survey Telescope (LSST) is one of three major ground-based facilities recommended for construction during the coming decade by the AASC. It also has been recommended by two other National Research Council (NRC) studies—one on priorities for solar system research and the other on priorities for studying problems on the interface between physics and astrophysics. With the capability of providing a digital survey of the entire visible sky every week or so to a deep limiting magnitude (~ 24 in a single optical band), the LSST will take advantage of developments in telescope and detector technology—as well as computational hardware and software—to open up new domains of astrophysical research. It would, for example, be possible to detect within a decade about 90 percent of all of the Near-Earth Asteroids (NEAs) with diameters greater than 200 m—i.e., nearly meeting the goal recently recommended by a NASA study committee of detecting potentially hazardous asteroids larger than 150 m in size. The data will also make it possible to derive orbital parameters. The LSST will detect about 10,000 supernovae per year, thereby making it possible to understand more accurately any systematics (such as reddening and evolution) that may affect the use of these events as standard candles. Observations of gravitational weak lensing will enable mass tomography and constrain the nature of dark energy. Scanning the sky with repeated short exposures, as is required for discovery of NEAs, also will open up studies of time-variable objects. Topics as diverse as the characterization of the galactic halo through light curves of distant RR Lyrae variables and the detection of gamma-ray afterglows could be tackled in a systematic way.

The LSST is necessarily a national project. The resulting database is likely to be one of the largest non-proprietary data sets in the world and will enable a rich range of scientific explorations that no single institution could begin to undertake. The success of the project depends on a range of new technologies—optical components, advanced CCD development, and especially the acquisition, archiving, and mining of large data sets—and will therefore require the active engagement of scientists and engineers from many different fields and institutions. As stated in the AASC report: “The construction and operation of LSST, together with the processing and distribution of the data, provide critical community service opportunities for an effective national organization for ground-based OIR astronomy.”

**LSST Design and Development**

NOAO has joined with the Universities of Arizona and Washington and the Research Corporation to form the LSST Corporation, which will carry out the project. Other members, including some Department of Energy laboratories, are likely to join in the near future. During the past year, the partners have developed a plan for the Design and Development phase of the project, which is estimated to cost ~$30M and last for 3 years. A proposal for half of the required funding has been submitted to the NSF. NOAO, DOE labs, and the Research Corporation, in collaboration with private donors, will supply the other half. The main deliverable is a fully
costed construction proposal, which we plan to complete by the end of the second year of the D&D effort. If cash flow is not the pacing item, first light can be achieved in the winter of 2011-2012. The baseline design that LSSTC is developing has a three-degree field with an 8.4-m primary telescope as devised by Roger Angel (Steward Observatory) and his collaborators, and subsequently optimized by Lynn Seppala (LLNL) and Ming Liang (NOAO).

A science working group (SWG) chaired by Michael Strauss has been established to define the design reference mission for the LSST. Its report is expected in FY 2004 and will be used in establishing the detailed science requirements for the LSST. Three science areas that have been highlighted to date are: (1) the characterization of small bodies in the solar system, (2) the study of variable objects, and (3) ultra-deep imaging with emphasis on weak lensing and as a method for constraining the properties of dark energy.

After the designs for both the LSST and PanStarrs have reached a greater level of maturity, and the costs, particularly of detectors, are better established, we will arrange for a down selection between the multi-PanStarrs concept and LSST, with the science requirements being used to guide the choice.

NOAO will take primary responsibility for construction of the LSST and enclosure and for developing the site. We are in the process of establishing the telescope team, which will include people with experience on the SOAR and Gemini projects. NOAO will also develop prototypes for some of the data pipelines and for the archive. Data management is the primary challenge of the LSST project, which will generate about five terabytes of data per night during routine operation. Certain information—particularly about variable, transient, and moving objects—must be extracted and made available in near real-time. The cost curve inferred from such projects as 2MASS and Sloan must be reduced by a factor of the order of five for the LSST project overall to be affordable. A number of precursor projects will provide both experience and test beds for LSST data management. The SuperMACHO project at CTIO is one example, and the data rates from ODI, the wide-field imager planned for the WIYN telescope, and the Dark Energy Camera, which has been proposed for the CTIO 4-m, approach LSST data rates closely enough to provide a real test for the data pipelines as they are developed for the LSST. NOAO is an active participant in the National Virtual Observatory (NVO) and currently is working on plans to serve data to the community from Pan-STARRS, the survey project being developed by the University of Hawaii.

DATA PRODUCTS PROGRAM (DPP)

The past decade has witnessed the advent of a number of ambitious astronomical surveys (Sloan Digital Sky Survey; 2MASS) that have just begun to exploit the parallel revolutions in digital detectors and computational power. The initial returns from these first-generation digital surveys are already impressive, ranging from the discovery of galaxies at $z > 5$, to gravitational microlensing events, to methane-dominated T dwarfs. As we look ahead, the astronomical community stands poised to take advantage of the continuing breathtaking advances in computational speed, storage media, and detector technology in two ways: (1) by carrying out new-generation surveys, and (2) by developing the software tools to enable discovery of new patterns and phenomena in the multi-terabyte (and later, petabyte) data sets that represent their legacies. In combination, new-generation surveys and software tools can provide the basis for enabling science of a qualitatively different nature. Whereas in the past, astronomical experiments were constrained by the need to carefully select small samples (often limited by a priori assumptions), we can now plan objective approaches based on deep images of wide areas of the
sky or spectra of millions of stars or galaxies. Furthermore, the archiving of surveys and other coherent data sets enables access by the entire community for defining samples, preparing observing proposals, and additional mining of the information.

These archives become a critical element of the national O/IR system and address the needs of researchers and educators who have limited access to telescope facilities and other opportunities. The potential of these revolutionary developments was recognized in the decadal survey, which recommended: (1) the development of a “national virtual observatory” (NVO) aimed at federating astronomical databases spanning the electromagnetic spectrum (the highest ranking initiative among AASC “small” projects); and (2) the construction of a Large-aperture Synoptic Survey Telescope (LSST) capable of mapping the entire visible sky once per week, thus enabling detection of variable/transient or moving objects by summing frames acquired over a decade, providing images of unprecedented depth. The panel for ground-based OIR astronomy also called particular attention to the need to develop archives for ground-based data.

**Major Program Goals FY 2004 – 2008**

Over the five-year period of this plan, the Data Products Program will address the opportunities described above by establishing a node of the NVO that specializes in ground-based O/IR data. This node will provide access to ground-based O/IR data (through the NOAO Science Archive) and services for the analysis and exploration of data, in addition to being a portal to other NVO providers. Because the largest single data set in this category is that from the LSST, the entire activity must be designed to accommodate an evolution to that scale, and must emphasize those tools and interface functions—such as visualization and analysis of time-domain data—that will be required for the community to exploit the LSST data set.

- Create an archive that supports data discovery, visualization, analysis, and mining for a combination of pointed observations and coherent surveys, together with derived, value-added data products. This archive should be scalable to handle the petabyte-scale data sets from projects such as LSST and Pan-STARRS.

- Put in place an automatic data transport infrastructure to feed raw data from NOAO telescopes automatically into a “save-the-bits” safe store within the NOAO Science Archive. This will incorporate all NOAO data into the NVO.

- Begin ingesting pipeline-reduced pointed observations from NOAO telescopes into the NOAO Science Archive; begin ingesting data from very large surveys, (e.g., Pan-STARRS, LSST) when they become available, perhaps as early as FY 2006.

- Continue to develop reduction and analysis software for NOAO and Gemini instruments, together with improvements in the IRAF system aimed at facilitating community development of new applications using IRAF.

**NOAO Science Archive (NSA)**

Work is now under way on the evolution of the “interim” NSA to an “engineered” facility that will be extensible to the LSST era. Additional efforts to improve functionality include development of time-domain, science-specific tools, development of visualization tools for O/IR
data, and integration of catalogs and other data products with image data in the archive. Future phases of this work will be carried out in collaboration with supercomputer centers.

**Data Reduction Pipelines**

Initial development is aimed at providing a common pipeline management infrastructure and specific modules to reduce data from the NOAO Mosaic CCD imagers. This will be followed by development of a pipeline for NEWFIRM. The University of Maryland participation is planned in this work.

**Data Transport Infrastructure**

Implementation of this system for automatic transport of data from telescopes to archives has major implications for operation of our facilities. Over the next year, this capability will allow both observing teams and archive researchers to begin accessing NOAO data directly from the NSA. The “save-the-bits” safe store will be incorporated into the archive, and data will be automatically mirrored between Tucson and La Serena.

**National Virtual Observatory (NVO)**

While the Data Products Program maintains involvement with the NSF ITR-funded effort in scientific and technical areas, an attempt is also being made to procure additional outside funding (via a recent NSF ITR proposal) to develop a computer model for the NVO that enables grid-based pipeline processing of massive data. Additional interests include the development of NVO services that support time-domain data and science.

**LSST Data Management**

The Data Products Program is focused on enabling effective community use of these and other large survey data sets. NOAO is participating in the LSST-partnership-wide effort to carry out exploratory and prototype work in support of a future LSST proposal. NOAO is also negotiating a partnership with the Pan-STARRS project in which DPP provides community access to useful Pan-STARRS data products as a precursor to the similar LSST effort.

**Instrument Data Reduction**

Collaboration with NGSC, CTIO, and KPNO instrument scientists continues to guide development of instrument data reduction software. In addition, software developers are working in collaboration with Gemini personnel to develop data reduction tools for Gemini instruments.
4 MAJOR INSTRUMENTATION PROGRAM

Over the past decade, there has been unprecedented investment in new telescopes in the 8-m to 10-m class. The challenges in the next decade will be to take full advantage of these facilities by equipping them with advanced technology instruments and to leverage that experience into construction of the first instruments for the next generation of telescopes. Experience with the first generation of 8-m telescope instrumentation shows that these instruments typically will each cost several million dollars, and their successful deployment will require effective partnerships between astronomers and professional engineers, and a systems approach with strong project management. In addition, coordination among the major astronomical observatories will be necessary to maximize the range of available capabilities and to optimize the expenditures on the infrastructure required to support the building of complex instruments.

Program Objectives

The principal objectives for the Major Instrumentation Program are to:

1. Establish a robust pipeline for delivery to the Gemini telescopes instruments that simultaneously meet performance, cost, and schedule requirements, in partnership with other major instrumentation providers
2. Supply key instrumentation technologies to the developers of instrumentation for other large telescopes in return for community access where appropriate
3. Develop the broad range of capabilities needed to serve as a prime contractor for the still larger and more complex instruments that will be required for the GSMT and LSST

The FY 2002-2006 Long Range Plan actually identified #3 above as a secondary objective. However, experience over the past year has clarified the importance of an early start in this area, so developing these capabilities has been put on a par with the first two objectives.

Decisions on the major work packages have been based on the principles outlined in the FY 2002-2006 Long Range Plan. First, the NOAO program will focus on major instruments (estimated total cost at least $6M with detectors and controllers), with priority given to building instruments for telescopes of 6.5-m aperture or greater. Second, the instruments must be integral to the strategic plan for the U.S. ground-based system of telescopes or synergistic with it. Third, the evaluation of instruments with respect to the strategic plan should be carried out in the context of community workshops on the national system.

Major Program Goals FY 2004 – 2008

- Complete, deliver and support commissioning of GNIRS (FY 2004)
- Design, construct, and deliver the NOAO Extremely Wide-Field Imager (NEWFIRM) (FY04-05)
- Complete MONSOON design, and build and deliver several working systems (FY 2004 and onward)
- Submit proposals in response to the current Gemini call for instrument study proposals (FY04-05)
Build at least one new instrument for Gemini, preferably in partnership with a university instrumentation group (FY 2005-2007)

Design, build, and commission an adaptive optics (AO) system for the SOAR telescope (FY 2004 – 2007)

Support testing and characterization of new CCD technologies needed for WIYN ODI and the Large-aperture Synoptic Survey Telescope (LSST) (FY 2004 – 2007)

Together with the AURA New Initiatives Office, establish and administer a structure for coordination of GSMT instrument conceptual designs, providing necessary system engineering and requirements flow-down and flow-up between instrument and telescope design (FY 2004 – 2008)

Submit at least one conceptual design for an instrument for the GSMT (FY 2005 – 2008)

Explore possibilities for participating in other 6-m to 10-m class instrument programs, either through collaborations or by direct proposal (FY 2005-2008)

**Major WorkPackages FY 2004 – 2008**

The following paragraphs give some background and description of the major work packages, showing their connections to the major program goals described above.

- **Complete, deliver, and support commissioning of GNIRS**

  GNIRS is a long-slit infrared spectrograph designed to record spectra of single objects at resolutions ranging from $R = 570$ to $R = 17800$. It will enable science ranging from studies of the evolution and properties of very low-mass stars and brown dwarfs, to studies of the formation and evolution of galactic bulges, to spectroscopy of very high-redshift galaxies. After overcoming some difficulties in fabrication and system integration, the GNIRS team has produced an instrument that successfully meets all the performance specifications tested to date, and was delivered to Gemini-South in autumn of 2003. As of this writing, it is currently in the final stages of commissioning. This project has demonstrated the critical importance of good systems engineering and project management and has provided valuable experience in both those areas. Completion, delivery, and commissioning of GNIRS position NOAO very favorably in the competition for the next round of Gemini instruments. This work package meets the first program goal of maintaining a robust pipeline for the delivery of Gemini instruments.

- **Design, construct and deliver NEWFIRM**

  NEWFIRM is a wide field near-IR survey camera designed to image a field almost 30 arcminutes square. Its science goals range from population statistics for methane brown dwarfs to searches for primeval galaxies at high redshift. An imager of this type was identified as one of the highest-priority needs of the US observing system by the NOAO-sponsored community workshop on the future of the US system (Scottsdale, October 2000). In addition to its intrinsic merits as an integral part of the US system of ground-based facilities, NEWFIRM allows NOAO to retain an essential core of engineers, designers and managers until the next Gemini instrument enters the design and construction phase. After a slow start in early FY 2003 (largely due to the demands of completing GNIRS), the NEWFIRM team has reorganized itself and successfully completed its Preliminary Design Review in June 2003, with a targeted delivery date late in FY 2005 or early in FY 2006. This work package meets the first goal, that of maintaining a robust pipeline for the delivery of...
Gemini instruments, by allowing NOAO to keep the core instrument design and construction team working between completion of GNIRS and the beginning of the next major Gemini instrument.

- Complete MONSOON design, and build and deliver several working systems

MONSOON is the NOAO-designed detector controller system that will be versatile enough to drive both optical CCDs and IR diode arrays, and scalable enough to control large mosaics of individual detectors. This capability is essential for the next generations of instruments with very large focal planes, beginning with NEWFIRM and continuing on through the next generation of Gemini instruments to LSST and even beyond. Also, MONSOON is designed to be sufficiently flexible that it can be used by other instrument making groups, and specific inquiries have been received from two groups outside of NOAO. The MONSOON team completed its first working prototypes in FY 2003 and held a successful status review for the first “production” systems in December 2003. FY 2004 will see the first system built for use in an NOAO instrument, NEWFIRM. The Major Instrumentation Program is developing a structured way of making MONSOON systems and their underlying technology available to the community at large. This work package meets the second program goal, that of supplying key instrumentation technologies to other builders, by directly supplying them with a critical subsystem that is not currently available elsewhere. It also meets the third program goal, that of developing the capabilities needed for GSMT and LSST instrumentation, by providing a path towards control of the massive focal planes that will be needed for those telescopes.

- Submit proposals in response to the current Gemini call for instrument study proposals

In December 2003 Gemini published Announcements of Opportunity to propose for design or feasibility studies on four specified instruments or systems. NOAO staff are participating at various levels in proposals relating to all four Announcements.

1. A design study for a large-format, cross-dispersed, high-resolution, near-infrared spectrograph that will provide complete coverage of all or most of each infrared wavelength band in one exposure at very high spectral resolution ($R \sim 70,000$). As requested by Gemini, the instrument will also incorporate a multi-object mode allowing simultaneous spectra of 15-30 objects at moderate resolution ($R \sim 30,000$). The science goals include more detailed analysis of the properties of brown dwarfs, star formation regions, active galactic nuclei, and high-redshift galaxies. NOAO is collaborating closely with the instrumentation group at the University of Florida on this proposal.

2. A feasibility study for a very wide-field, very heavily multiplexed, multi-object, fiber-fed optical spectrograph that will record spectra of several thousand objects at a time. This feasibility study is to focus on reducing the uncertainties in the operational supportability of this large system, and on better estimating its cost. The science goals include measurement of the equation of state of the universe through a very wide-field, very deep redshift survey, and determination of the age and formation history of the galactic halo. NOAO is participating in this proposal through a large international collaboration led by the Anglo-Australian Observatory.

3. A design study for a very high-order adaptive optics system with a coronagraphic imager for direct observation of giant planets orbiting nearby stars. The science goals include a census of nearby extrasolar planets, and initial studies of the physical properties of the planets detected. NOAO is supporting a proposal from the University of Arizona for this study.
4. A feasibility study for an adaptive optics system capable of correcting only the ground-layer atmospheric turbulence but over a relatively wide field. This feasibility study is to address more broadly the question of whether such a correction is even possible on an 8-meter telescope, and if so over what field of view. NOAO is supporting a proposal from the University of Arizona for this study.

All of these are large, complex instruments that offer numerous opportunities for collaboration with other instrument building groups including and beyond those mentioned above, both at U.S. universities and at national facilities in other Gemini partner countries. This work package meets the first program goal—that of maintaining a robust pipeline for delivery of Gemini instruments—by providing essential input to that pipeline in the form of intellectual investment in next-generation instrumentation, and by doing so through collaborations with other instrument-building teams.

- **Build at least one new instrument for Gemini, preferably in partnership with a university instrumentation group**

We anticipate that at least one of the proposals mentioned above will be successful, resulting in the next major project for the core instrumentation group at NOAO. In addition, such a project would present an excellent opportunity to join or lead a partnership with another institution, thus realizing the organizational model that would be needed for building even larger instruments for the GSMT and LSST. The exact nature and scope of this work package clearly depends on developments yet to happen, but according to the schedule in the Gemini Announcements, construction contracts for the first instruments of this new generation would not begin until at least calendar year 2005. This work package meets the first program goal—that of maintaining a robust pipeline for delivery of Gemini instruments—by actively constructing an instrument in partnership with another institution, thus fostering the instrument-building capabilities at both NOAO and the partner.

- **Design, build, and commission an adaptive optics (AO) system for the SOAR telescope**

A properly designed AO system will allow the SOAR telescope to provide low-order partial seeing corrections at shorter wavelengths (optical and ultra-violet) than can be achieved on larger telescopes. Further, such a system, in combination with a Rayleigh laser artificial guide star, would provide an ideal test bed for the technology of “ground-layer adaptive optics” (GLAO) seeing improvements that are essential to several science goals of a Giant Segmented Mirror Telescope (GSMT). Finally, such a system gives NOAO staff experience in the AO field that will be critical in building instruments for the GSMT. The design work for this AO system has already begun, and the design underwent a conceptual review in April 2003 and a follow-up “delta review” for changes in January 2004. There are still a number of issues to resolve with the design and with the plans and resources needed for construction, but it is expected that the system will be ready for a Preliminary Design Review in the second half of FY 2004, with construction beginning shortly thereafter. Construction is expected to proceed in two phases—the first being the development of a system capable of limited use with natural guide stars, and the second being the integration of the laser artificial guide star for full-sky ground-layer correction. This work package meets the second program goal—that of supplying key technologies in return for community access—by satisfying part of NOAO’s obligation to provide two additional instruments to the SOAR consortium in return for continued community access. It also meets the third program goal—that of developing the technology and capabilities needed for next-generation telescopes—by providing a test bed for GLAO technology and giving the NOAO staff critical experience with AO developments.
- **Support testing and characterization of new CCD technologies as needed for WIYN ODI and LSST**

The next generation of visible-light instruments will require CCD technologies that do not currently exist. Some applications will need detectors with extremely high quantum efficiency in the red wavelengths but without the severe fringing exhibited by most current high-efficiency devices. Other instruments will require the ability to shift charge by small amounts in both directions, in real time, to follow the seeing-induced movement of the point spread function. The WIYN One-Degree Imager likely will be the first instrument to need one of these technologies, but ultimately the success of the LSST depends on their availability. NOAO should develop its CCD testing and characterization facilities to play a leading role in the specification and testing of these needed capabilities. Infrastructure and staffing improvements in this area are proposed for the FY 2005 budget, with the first rounds of testing beginning in parallel. It is most likely that this testing would be a long process continuing over several years. This work package directly meets the third program goal—that of developing the capabilities needed for LSST and GSMT instrumentation. It also could meet the second goal of supplying key technology to other developers of instrumentation in return for community access.

- **Together with the NIO, establish and administer a structure for coordination of GSMT instrument conceptual designs, providing necessary system engineering and requirements flow-down and flow-up between instrument and telescope design**

It is important to set up such a structure early in the conceptual design of the GSMT itself, so that the requirements of the instruments can be determined based on the science drivers, and then those requirements can be connected rationally to the capabilities and requirements of the telescope before the telescope design is frozen. The Major Instrumentation Program (MIP) should work closely with the New Initiatives Office and with any GSMT partners to establish an office staffed with the scientific and systems engineering expertise. This will provide the needed two-way connection between telescope requirements, as developed by the telescope designers, and instrument requirements, as developed by various instrument building teams within NOAO and at partner institutions. This office also should coordinate the preparation of instrument concept studies at partner institutions, ensuring that standards for rigor and detail are observed and that interfaces are logically and consistently specified. The development of this structure is beginning in FY 2004 through MIP participation in the instrument working group for one of the large telescope consortia, and is to continue throughout the design and construction phase of the GSMT and its instruments. This work package directly meets the third program goal, that of developing the capabilities needed for LSST and GSMT instrumentation.

- **Submit at least one conceptual design for an instrument for the GSMT**

Hand-in-hand with the establishment of a coordination structure for GSMT instrument design, NOAO should take an active role as one of the instrument design teams, both to provide intellectual involvement for the scientific and instrumentation staffs at NOAO, and to ensure a healthy level of competition among the teams designing GSMT instruments. This is precisely the model followed with great success by the European Southern Observatory (ESO) for building Very Large Telescope (VLT) instruments. The ESO provided the services of coordinating instrument and telescope designs, specifying standards and interfaces, and monitoring progress toward meeting the standards. The ESO also built one complete instrument itself, maintaining its position as a builder within the community. At NOAO, this effort will require the involvement of a full instrument design team led by a scientist and coordinated by a project manager. Again, this work should begin as soon as practical and continue for several years. This work package directly
meets the third program goal, that of developing the capabilities needed for LSST and GSMT instrumentation.

- **Explore possibilities for participating in other 6-m to 10-m class instrument programs, either through collaborations or by direct proposal**

NOAO should broaden its outlook and investigate the possibilities of building instruments for existing or near-future facilities beyond Gemini. For example, the ESO has awarded all or large parts of instrument construction grants to a U.S. university and to the Anglo-Australian Observatory. There is no reason in principle why NOAO should not also propose to build an instrument for an organization like the ESO. Subaru and GranTeCan are additional possibilities. Looking down the road, there are also European or international collaborations proposed for telescopes in the “30-m and up” class, such as Euro50 and OWL. In preparing for construction of GSMT instruments, NOAO also should be open to the possibilities of proposing an instrument for an international facility. This effort should begin in FY 2005 as an exploration by MIP management of the opportunities and challenges. It is impossible to predict how much actual work may come from this effort, or by when, but beginning the exploration in FY 2004 may result in a proposal, study, or project within the horizon of this Long Range Plan. This work package meets the second program goal of supplying key technology to other instrument developers in return for U.S. community access, and the third program goal of developing the capabilities needed for GSMT and LSST instrumentation.

**Program Components**

The following elements are important to achieving the goals of the Major Instrumentation Program:

- Strong in-house capability in project management, as well as in the core engineering disciplines: systems, optical, mechanical, electronics, and software. As instrumentation projects grow and partnerships become the norm for instrument development, strong project management will become even more important. NOAO must build on its already good reputation in this area.

- A program to develop, test, characterize, and deploy detectors and controllers. The needs for even larger and more capable focal plane arrays will continue through the next generations of instruments and telescopes. Again, NOAO can cement a key position in these next generations by continuing to build on its recognized strengths in these areas, as exemplified by the ORION detector program and the MONSOON controller development.

- Infrastructure adequate to support the integration and testing of large instruments, including a telescope simulator. This infrastructure will be made available to community instrumentation groups and to NOAO projects.

- A program to develop and evaluate a limited number of new key technologies, as exemplified by recent contributions to the international efforts to further the development of vacuum phase holographic gratings.

- A program to train post-doctoral associates in the skills required to provide scientific leadership in the building of large instruments, and an intern program expanded to include graduate students.
Project Phases and Resources

The phases in the construction of a major instrument are: (1) the development of a concept design and proposal, (2) detailed design, fabrication, integration, and testing, and (3) commissioning at the telescope. The staffing through these stages is dynamic, with emphasis on scientists and engineers in the early and late stages, and with the addition of designers and instrument makers in the middle stages. It typically takes a minimum of four years from the time an instrument is selected for funding to the time it is ready to be shipped to the telescope, although some instruments can take significantly longer. From the standpoint of smoothing out the cash flow and manpower requirements, it makes sense to undertake two instruments, staggered by two years, and this indeed was the model recommended for the NOAO program in the FY 2002-2006 Long Range Plan. However, reality has a way of being too messy and uneven to permit this kind of neat phasing. This problem was made painfully clear when Gemini awarded the construction of the Gemini South Adaptive Optics Imager (GSAOI) to another institution, leaving NOAO without an externally funded project just as the GNIRS project is winding down. In general, Gemini does not call for proposals for a new instrument on a neat two-year cycle, nor can NOAO expect to win the competition every time or even every other time. It does not make sense to plan on starting a new Gemini instrument every two years.

Since the FY 2002-2006 Long Range Plan was drawn up, there has been further work to make both the LSST and GSMT more real, and both programs are beginning to enter phases where some work on their instrumentation is needed in technology development and conceptual design. However, this work is of a much longer range and riskier nature than the four-years-to-build envisioned in the two-instrument model. NOAO must be prepared to invest some seed money over the next couple of fiscal years without any assurance that a full instrument construction project will follow.

In FY 2004, NOAO is entering construction on its next major instrument (NEWFIRM) just as the last (GNIRS) is completing commissioning. In this context, it makes more sense to focus on building one instrument at a time (which is all that can be done by the current core group anyway), and to shift efforts toward proposing for future Gemini instruments and longer range development of instrumentation ideas and technologies for the next generation of telescopes. Such a program would also re-emphasize the importance of building future instruments through partnerships with university instrumentation programs.

The FY 2002-2006 Long Range Plan envisioned growth in the base budget for major instrumentation over each of the five fiscal years. Some growth of this nature is absolutely essential to sustaining a viable program, even at less than the two-instrument model. Building one instrument at a time while simultaneously submitting proposals for the next Gemini round and supporting the longer range investments needed for the GSMT and LSST will require budget growth adequate to support the additional scientists and engineers needed for the proposals and development work. Without that sort of growth, the MIP will be unable to prepare for the future, and will be totally dependent on uncertain outcomes in Gemini instrument awards.


5  SCIENCE EDUCATION AND PUBLIC OUTREACH

MISSION AND OBJECTIVES

The overall mission of the NOAO Office of Public Affairs and Educational Outreach (PAEO) is to advance the cause of science education and science inquiry in all sectors of American life using the interdisciplinary appeal of astronomy. Our ultimate goal, consonant with NSF Education and Human Resources priorities, is to contribute to the development of a scientifically literate citizenry capable of meeting the science, mathematics, engineering, and technology challenges of 21st-century society.

The use of NOAO science and its unique facilities as the framework for promoting public understanding, awareness, and support of U.S. science also underscores NOAO outreach activities to the non-specialist public. Whether via NOAO’s public-friendly Web site (www.noao.edu), the popular exhibits and guided tours at the Kitt Peak Visitor Center, or the stream of press releases and scientific news items produced by the Media and Public Information group, NOAO regularly communicates the excitement and significance of astronomical research to a wide range of audiences.

NOAO PAEO programs are governed by two main principles:

- We will provide top-quality products and services in all of our outreach activities, incorporating the latest research results from the national observatory wherever possible.
- We will provide national leadership and exemplary program models in astronomy education, whether our immediate audience is local, regional, national, or international.

Major Program Goals FY 2004 – 2008

This Long Range Plan emphasizes excellence in these fundamental areas through a range of high-visibility programs. NOAO PAEO is organized to create a synergy across our department that allows us to innovate and respond to the most pressing needs of the entire formal and informal educational system, without becoming overly devoted to one area.

Science Education

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. This broad view is necessitated by the international nature of astronomy and the geographic distribution of NOAO-supported facilities. Our program staff have a keen awareness of our obligation to reach underserved groups, and to constantly be a source for developing and testing novel ideas.

Our educational program goals emphasize national leadership even as many of our educational programs serve a local and regional audience. Our goal is to provide “flagship” programs that illustrate both best practices and new approaches in the field. Current and future NOAO EO efforts span the educational spectrum, including:
Teacher professional development
Teacher-astronomer partnerships
Instructional materials development
Informal and community-based science education
Research experiences for students and teachers

Our programs are designed to extend beyond a narrow “astronomy-only” focus to include technology education, optics education, and the physical sciences, based on the realization that the field of astronomy has a strong instrumentation/engineering component and that astronomy education in the public school community is often a part of Earth science education. Thus we extend our programs to encompass an understanding of technology, and we base our formal education programs on a willingness to work with and to be part of the larger earth and space science education community.

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

1. Strategic partnerships with professional societies such as the American Astronomical Society, the Astronomical Society of the Pacific (ASP), the American Geophysical Union, the Optical Society of America, SPIE/the International Society for Optical Engineering, and the Geological Society of America

2. Cooperation with educational societies and organizations such as the American Association of Physics Teachers, the National Science Teachers Association, the National Association of Earth Science Teachers, the Association of Science Technology Centers, and the International Dark-Sky Association

3. Active teaming arrangements with our closest geographic partners, including the VERITAS project, the University of Arizona, Steward Observatory, and the Flandrau Science Center

4. 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 support for a new class at the Tohono O’odham Community College.

To work effectively with these organizations, NOAO EO staff often serve on advisory committees and proposal review panels, chair education sessions, and run workshops as part of professional meetings. The NOAO educational outreach staff, which includes four Ph.D.-level educators with extensive experience in a variety of major educational outreach efforts in astronomy and space science, has given more than 40 presentations at conferences in the last five years on innovative methods in science education.

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 that data for educational purposes, leading toward the data-intensive era of the LSST.
**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, all educational programs for visiting school classrooms and the general public, and the popular nighttime observing experiences for both the general public and advanced amateurs. 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 60,000 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 audiovisual displays and updates to its colorful display posters, along with the addition of more hands-on exhibits and interactive activities led by docents. The daily revenues generated by the Visitor Center attendees and programs help to offset some of the costs of NOAO’s Public Outreach activities, including much-needed capital improvements to the Visitor Center building.

The Kitt Peak docent program—which includes three daily tours of the Mayall 4-m, the 2.1-m, and the McMath-Pierce solar facility—constitutes a rewarding volunteer experience for the 30 docents themselves and also provides invaluable support to the public education mission of the Visitor Center. A new and more in-depth educational training program for Kitt Peak docents has been in effect since 2001.

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 23,000 participants since its inception in 1996. Each NOP session features an in-depth, three-hour observing experience for up to 34 people at the two sites. Participants use star charts, binoculars, and the 0.6-m telescope at the Visitor Center Observatory or the 0.4-m telescope at the new site to gain an in-depth understanding of the wonders of the night sky.

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 (with no more than four participants per session) that uses the Visitor Center telescope outfitted with a CCD camera operated with the help of an NOAO Public Outreach telescope observer. This unique and popular program attracts participants from around the world and receives positive publicity in both tourism and amateur astronomy publications.

**Major Program Activities FY 2004 – 2008**

**Science Education**

*Teacher Leaders in Research Based Science Education (TLRBSE)*

The TLRBSE program is a cornerstone activity of NOAO educational outreach. TLRBSE competitively selects about 20 experienced middle school and high school teacher leaders
annually from across the United States 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. These master teachers in turn are prepared to mentor novice teachers in their local area, helping with the ongoing challenge of teacher retention and renewal. In the process, TLRBSE is developing a leading model for Internet-based, actively moderated distance-learning course that encompasses pedagogy, leadership, and science content.

Over the next five years, as the program becomes fully funded within the core NSF AST budget for NOAO, TLRBSE will grow to offer an even greater range of research experiences to its ever-expanding cadre of trained master teachers (>100 and counting), from observing on Kitt Peak to the use of small remote telescopes to cutting edge astronomical facilities ranging from the Spitzer Space Telescope to the VERITAS array.

TLRBSE program will be maintained at its current level of quality and depth as it becomes completely supported in the core program. TLRBSE represents our flagship teacher professional development program and is a national model for teacher enhancement and the value of incorporating science research into the middle and high school classroom.

**Project ASTRO**

Project ASTRO forms the core of NOAO’s highly successful regional educational outreach program. Project ASTRO-Tucson is a flexible program with broad content coverage and great utility for a diverse educational audience.

Project ASTRO is aligned with the National Science Education Standards, it appeals to different teaching and learning styles, and it can be adapted for constraints on space, staff, and money at individual schools. It also addresses the scientific process, best practices and pedagogy, student misconceptions, and authentic assessment issues. 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. One of 13 sites nationally, ASTRO-Tucson has reached more than 14,000 students via nearly 400 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.

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. Because it can be adapted to address the needs of a diverse audience and varied circumstances, Family ASTRO has experienced immediate success and acceptance in Tucson and elsewhere, which has led us to incorporate it as a long-term commitment to local and regional outreach in the informal arena.
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 exchanged methods and ideas about how to explain and demonstrate the nature of light and color to students of various ages. Each workshop was held in Spanish with bilingual science teachers from the Tucson area. The workshops are envisioned as the beginning 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. Future areas of emphasis will likely include the common issue of dark skies and light pollution.

Astronomy and space science educators cannot easily find high-quality instructional materials in Spanish for elementary and secondary formal education; informal educational materials in Spanish are difficult to find at all levels. With its strong connections to Spanish-speaking science teachers and science district coordinators, NOAO is creating a national resource to enable educators to find and apply quality materials in Spanish that have already been produced.

This NOAO Spanish Language Materials Educational Center is providing a Web-based, user-friendly catalog of generally available Spanish language materials for all grade levels in astronomy and space science. Published in both Spanish and English, the Web pages include materials appropriate for school guidance counselors, administrators, and teachers.

New Programs in Educational Outreach

Consistent with our educational outreach philosophy and as part of our strategic partnerships with professional societies and educational institutions, we have established a variety of innovative teaming arrangements.

NOAO has several ongoing partnerships with the Flandrau Science Center, including a joint effort with the University of Arizona in an NSF-funded project titled “Revealing the Invisible Universe From Nanoscopes to Telescopes”, a program to train student interns in informal science education.

NOAO is also a key partner with the Optical Society of American and SPIE-The International Society for Optical Engineering, in a project called “Hands-On Optics”, funded by the NSF Informal Science Education. NOAO will develop optics instruction modules and provide professional development for this program, which will reach more than 40,000 middle school students in after-school programs.

NOAO is 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. The NOAO manager of science education and other staff will be key contributors to a new NSF Instructional Materials Development program titled “Investigating Astronomy,” which will develop a high school astronomy curriculum in partnership with the Astronomical Society of the Pacific and TERC.

These projects serve as preparation for the data and technology rich efforts required to support the education and outreach programs proposed for the LSST and GSMT.
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 has encouraged 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.

Astronomy Education Review

The Astronomy Education Review (http://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 completed its second year using start-up funding from NASA, and is endorsed by both the AAS and the ASP.

The 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.

Public Outreach

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. Development of new brochures, television commercials, and marketing pieces will continue to be tied into an overall marketing plan for the Visitor Center with the goal of increasing the number of visitors to the mountain, thus informing larger numbers of people directly about the mission of NOAO and the NSF, and providing a better taste of the excitement and rewards of scientific research.

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. Some new initiatives include working with the Boy/Girl Scouts and other similar clubs on special stargazing nights. Classes are being offered to the general public on such topics as asteroid hunting, solar observing, CCD imaging, the Moon, and an introduction to astronomy as a hobby, and the intent is to expand the number and type of these classes/special programs in the next five years.

One special focus is increasing the number of school groups visiting Kitt Peak, with the aid of science education students from the University of Arizona and a grant from the NSF for the
The development of curriculum and hands-on activities for schools wishing to visit the mountain. A greater concentration on marketing, along with the production of a planning guidebook for teachers, will be implemented in the near future, with the goal of enticing greater numbers of students to visit the mountain. When staff time and resources allow, we also intend to develop a wider variety of in-situ outreach programs to local schools, aided by low-cost cooperation such as recently initiated loans to NOAO of the mobile StarLab planetarium owned by the UA Flandrau Science Center.

The Visitor Center staff and 0.4-m telescope are an integral part of the TLRBSE teacher professional development program on Kitt Peak. With these activities taken in total, it likely will be necessary to add an educational coordinator to the PAEO Public Outreach staff in the 2004-2005 time frame.

NOAO Public Outreach group has begun to prepare a campaign to establish a “Friends of Kitt Peak” public support group which, in return for a nominal membership fee, will receive a newsletter and opportunities to experience special events on the mountain. Such a group will enable PAEO to develop a donor base for the possible major expansion of the Visitor Center facilities and a purpose-built second public observatory in the 2008 time frame.

The NOAO Public Outreach group will 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. A new marketing relationship with Lowell Observatory and the Challenger Center for Space Science Education near Phoenix is also being explored.

**Exhibit Expansion and Improvements**

- Continue Visitor Center exhibit upgrades underway (Gemini virtual tour, mountain topography, infrared camera activities, etc.)
- Complete interpretative master plan
- Add the following exhibits:
  - *What are astronomers doing tonight?*
  - *Tohono O’Odham (refurbish and expand)*
  - *Natural History of the Mountain*
  - *NOAO science/observatories*
  - *Dark Skies*
  - *Instrumentation*

**Staffing/Tours**

- Develop walking tour info booklet and routes
- Offer several new pay specialty tours possibilities (4-meter, WIYN, VERITAS)
- Offer transported specialty tours (historical)
- Double the number of docents
Membership Programs and Marketing

- Hands-on science in place at the Visitor Center
- Expand class and program offerings
- School Program on-site in place, with related offsite marketing
- On-line store
- Develop a “Friends of Kitt Peak” membership group for improved marketing
- Develop fundraising plan and begin raising donations
- Signage replacement
- Build ticket window

NOP/AOP

- On-line RSVP system for NOP
- Double the number of AOP guests
- Work toward development of an off-site NOP at a local resort, etc.

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 plans to expand its media outreach into the growing world of Internet Webcasting by offering Real Video press conferences based on newsworthy results as they are published. (This Webcasting equipment will also be utilized for distance learning-based educational outreach programs and by project offices within NOAO, such as the two pathfinder programs done by NGSC, to communicate with their users and advisory groups.)

The NOAO home page on the Web will continue to be programmed with the central principle of presenting a clear and interesting site for a Web surfer from the general public.

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, as evidenced by recent NOAO-related stories published by Associated Press and Reuters wire services, CNN.com, ABC-TV, and USA TODAY. Live local news and weather broadcasts from Kitt Peak resumed in February 2004, and are expected to be more frequent in the future.
The NOAO Image Gallery (http://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 site “Astronomy Picture of The Day.” 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. Past collaboration in science news and imagery with the Space Telescope Science Institute and Chandra X-Ray Observatory has expanded to include the Spitzer Space Telescope, and these collaborations are only expected to grow—highlighting the synergistic relationship between ground-based and space-based infrared astronomy—and in the process, the connectivity between NSF and NASA.

Proposed major program initiatives such as the GSMT and LSST will be highlighted by new information products on the Web, related displays and exhibits at the meetings of the AAS (where the GSMT Book was distributed in January 2003, for example), and other external organizations such as the International Dark-Sky Association. Each of these programs has an extensive developmental outreach program tied to successful D&D phase funding.

The future goals of NOAO—and the observatory’s emerging roles in the larger astronomical community—are an integral part of the quarterly NOAO Newsletter, which has evolved to a more appealing format and layout. It will continue to be a key source of information for NOAO’s many disparate customers, partners, and public stakeholders.
NOAO BUSINESS PLAN: FY 2004-2008

The five-year Cooperative Agreement which commenced in 2003 encompasses new directions for NOAO, including the challenge of funding new program initiatives aligned with the decadal survey within a level budget. NOAO is meeting these challenges by working in partnership with institutions in the LSST Corporation to carry out design and development for that facility, and with institutions in the Thirty Meter Telescope consortium to advance design and development of the GSMT up to preliminary design review. In FY 2004, an instrumentation partnership with the University of Maryland went into operation. A new partnership in the form of the Small and Moderate Aperture Research Telescope System (SMARTS) consortium succeeded in operating three of the four small telescopes on Cerro Tololo. Together these changes have resulted in significant cost reductions at KPNO and CTIO.

In plotting a business plan for NOAO’s four divisions for FY 2004-2008, we show the Work Breakdown Structure (WBS) below the program level (8 in number) to extend to functions (10 in number) that are, in most cases, common to more than one division. Hence, Table 1 has 18 line items corresponding to these programs/functions.
Level 2 Budget Tables FY 2004 – 2008

The work breakdown costs listed as line items in Tables 1 through 5 below are defined as follows.

- **Science Operations/System.** The work package that carries out the telescope time allocation process (TAC) and supports several meetings through which NOAO interacts with the community, specifically the NOAO Users’ Committee and the annual meeting of the NOAO survey teams. Administration and proposal review for the Telescope System Instrumentation Program (TSIP) are included in this function, for which the NOAO deputy director is responsible. The Adaptive Optics Development Program (AODP) is included in the function too, but management of this program is by the Associate Director for GSMT Development, assisted by Stephen Ridgway.

- **Instrument Upgrades.** Includes projects such as detector or controller upgrades or commissioning of new capabilities. Instrument upgrades are management responsibilities of the CTIO and KPNO directors.

- **Computer Infrastructure Support (CIS).** Computer system support to each division, network maintenance, and software support. CIS is a management responsibility of the NOAO and CTIO deputy directors.

- **Telescopes.** Operations, upgrades, and software support work packages by telescope. Telescope A refers to the Mayall at KPNO, the Blanco at CTIO, and Gemini user support in the NGSC division, respectively. Telescope B is the WIYN at KPNO, the SOAR at Cerro Pachón, and Gemini South operations support. Telescope C refers to the other telescopes at KPNO and CTIO. The CTIO packages contain projected operational costs as per the annual AOSS agreement between tenants. The decline of support in CTIO Telescope C reflects its reduced operational role in the newly formed Small and Moderate Aperture Research Telescope System (SMARTS) consortium to operate three of the four small telescopes located on Cerro Tololo.

- **Mountain Facilities.** Building maintenance, kitchen and accommodations, and roads, grounds, and utilities at CTIO and KPNO. At CTIO, some of the costs are allocated through the AOSS structure and annual agreement of the tenants.

- **Staff Research.** Costs of scientific staff research, administration of scientific staff, travel, and publications. The staff research program is the management responsibility of the associate director for science. The Staff Research NGSC entry in Tables 2-5 supports benefits and incidental expenses for the NGSC Fellows and Post Doctoral programs.

- **Director’s Office.** Administrative support, Tucson library, risk management and safety coordination.

- **Headquarters.** Central facilities operation costs of non-mountaintop building maintenance, roads and grounds, utilities, vehicles, and the computer network. The Tucson infrastructure program is the responsibility of the Associate Director for Administration and Facilities.
• **Central Administrative Services (CAS).** Human resources, accounting and financial management, sponsored projects, procurement, payroll work packages, and AURA corporate and other AURA center support. Headquarters and CAS are management responsibilities of the Associate Director for Administration and Facilities in Tucson and the CTIO director in La Serena.

• **Public Affairs/Outreach.** Science education and public outreach programs, REU programs, public affairs, and graphic arts creation.

• **LSST.** Preparation and implementation of a technically sound and well-budgeted proposal for the Large-aperture Synoptic Survey Telescope (LSST) program. NOAO is committed to a construction and operations partnership in the LSST Corporation for the duration of the design and development phase. Logistical support is also provided for the LSST Science Working Group.

• **ETS Infrastructure.** Costs of management, administrative, training, travel, and contract hire expenditures, as well as AOSS charges. The operation and maintenance components and upgrades of the ETS infrastructure are also included. In NGSC, this work package refers to instrument development and project oversight of instruments for Gemini in the U.S. community. ETS infrastructure is the management responsibility of the associate director for instrumentation in Tucson and the CTIO Director in La Serena.

• **Data Products.** All planning, administrative, and day-to-day management of the Data Products Program for both DPP North and DPP South. Efforts required to expand the interim archive involve all data sets in the NOAO Survey Program and initial storage of raw data from both CTIO and KPNO; design and implementation of a fully engineered archive facility for NOAO; increasing management of the day-to-day archive system, media, and user support; and cross-divisional support for development of major IRAF system utilities, NGSC instrument data reduction software, data management planning for the LSST, and other initiatives.

• **NIO/GSMT.** Support for the AURA New Initiatives Office in the development of a Giant Segmented Mirror Telescope (GSMT); science merit functions; integrated modeling of GSMT design concepts; site testing in NOAO South; cost estimates; developing a road map for technologies for ELTs and their instruments; and exploring partnerships that will advance the design and support of a GSMT concept to ensure national community involvement. AURA is a partner in the TMT collaboration for the design and development phase.

• **Major Instrumentation.** Includes NOAO North and NOAO South completion of design and fabrication of instruments; responses to calls for proposals for instruments; continuation of support as requested to other NOAO/NSO programs, including LSST, KPNO, CIS, NSO, and GONG, as well as some outside programs such as Gemini and Steward Observatory; and support and maintenance for the infrastructure (shops, labs, and so on) used by MIP and other programs at the current level of functionality.

• **Servicing External Entities.** Under KPNO, this line refers to the costs of technical support of NSO and other tenants on Kitt Peak.
• **AURA Support and Management Fee.** Listed under the Tucson column in all years. The number listed under NGSC for this line item ($100,000 in FY 2003) refers to the cost of AURA’s U.S. Gemini Fellowship Program and is therefore a budget item *separate and distinct* from the AURA management fee. Under the new Cooperative Agreement, the AURA management fee is calculated based on a G&A indirect rate of 1.97% and an additional negotiated flat fee amount of $150,000.

• **Telescope System Instrumentation Program (TSIP).** This activity includes solicitation of proposals, review of the proposals by a peer-review committee, negotiation of sub-awards and oversight of the instrument development activity funded under a separate SPO program and administered by NOAO.

Funding allocations within divisions/programs in tables 3-5 are based on FY04-FY05 work package structures. NOAO operational base funding for all the tables have been determined as follows:

FY04 – Already submitted and approved by NSF and a result from NOAO’s budget allocation process and NSF funding cycle.

FY05 – Based on information provided by NSF and is currently undergoing the NOAO Budget allocation process and within the NSF FY05 funding cycle.

FY06 – Based on original AURA proposed yearly funding for the current Cooperative Agreement.

FY07 – Based on original AURA proposed yearly funding for the current Cooperative Agreement.

FY08 – Based on the FY05 proposed budget and structure, extrapolated to 2008. The current Cooperative Agreement ends 9/30/07 and a new proposed budget will need to be submitted.
Table 1
NOAO FY04 Funding Allocation
By Division and Program
Total = $26,528
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Program/Division</th>
<th>KPNO</th>
<th>CTIO</th>
<th>NGSC</th>
<th>Tucson</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Ops/System</td>
<td>103</td>
<td>103</td>
<td></td>
<td>255</td>
<td>461</td>
</tr>
<tr>
<td>Instrument Upgrades</td>
<td>125</td>
<td>158</td>
<td></td>
<td></td>
<td>283</td>
</tr>
<tr>
<td>Computer Infra. Support</td>
<td>479</td>
<td>400</td>
<td></td>
<td></td>
<td>879</td>
</tr>
<tr>
<td>Telescope A</td>
<td>1,463</td>
<td>925</td>
<td>94</td>
<td>2,482</td>
<td></td>
</tr>
<tr>
<td>Telescope B</td>
<td>896</td>
<td>799</td>
<td>186</td>
<td>1,881</td>
<td></td>
</tr>
<tr>
<td>Telescope C</td>
<td>370</td>
<td>26</td>
<td></td>
<td>396</td>
<td></td>
</tr>
<tr>
<td>Mountain Facilities</td>
<td>655</td>
<td>129</td>
<td></td>
<td>784</td>
<td></td>
</tr>
<tr>
<td>Staff Research</td>
<td>855</td>
<td>0</td>
<td>1,550</td>
<td>2,405</td>
<td></td>
</tr>
<tr>
<td>Director's Office</td>
<td>213</td>
<td>244</td>
<td>208</td>
<td>718</td>
<td>1,383</td>
</tr>
<tr>
<td>Headquarters</td>
<td>152</td>
<td>827</td>
<td></td>
<td>979</td>
<td></td>
</tr>
<tr>
<td>Central Admin. Svces</td>
<td>264</td>
<td></td>
<td>796</td>
<td>1,060</td>
<td></td>
</tr>
<tr>
<td>Public Affairs/Outreach</td>
<td>54</td>
<td></td>
<td>745</td>
<td>799</td>
<td></td>
</tr>
<tr>
<td>LSST</td>
<td>44</td>
<td></td>
<td>1,204</td>
<td>1,248</td>
<td></td>
</tr>
<tr>
<td>ETS Infrastructure</td>
<td>272</td>
<td>131</td>
<td></td>
<td>403</td>
<td></td>
</tr>
<tr>
<td>Data Products Program</td>
<td>292</td>
<td></td>
<td>1,038</td>
<td>1,330</td>
<td></td>
</tr>
<tr>
<td>NIO/GSMT</td>
<td>502</td>
<td></td>
<td>1,023</td>
<td>1,525</td>
<td></td>
</tr>
<tr>
<td>Major Instrumentation</td>
<td>611</td>
<td></td>
<td>2,860</td>
<td>3,471</td>
<td></td>
</tr>
<tr>
<td>Svc External Entities</td>
<td>76</td>
<td></td>
<td></td>
<td>76</td>
<td></td>
</tr>
<tr>
<td>AURA Support/Mgmt Fee</td>
<td>52</td>
<td>630</td>
<td>682</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Division</strong></td>
<td>$3,901</td>
<td>$5,910</td>
<td>$671</td>
<td>$12,046</td>
<td>$22,528</td>
</tr>
<tr>
<td><strong>TSIP Funds</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$4,000</td>
</tr>
<tr>
<td><strong>TOTAL NOAO Operational and TSIP Funds</strong></td>
<td>$26,528</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FY04 Allocation Funding Only
CTIO column represents all funds for programs and operations in NOAO South.
TSIP Annual funding includes estimated NOAO administrative costs
Table 2
NOAO FY05 Est. Funding Allocation
By Division and Program
Total = $28,123
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Program/Division</th>
<th>KPNO</th>
<th>CTIO</th>
<th>NGSC</th>
<th>Tucson</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Ops/System</td>
<td>122</td>
<td>108</td>
<td>293</td>
<td></td>
<td>523</td>
</tr>
<tr>
<td>Instrument Upgrades</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Infra.Support</td>
<td>546</td>
<td>424</td>
<td>424</td>
<td>970</td>
<td></td>
</tr>
<tr>
<td>Telescope A</td>
<td>1,224</td>
<td>1,187</td>
<td>277</td>
<td>2,687</td>
<td></td>
</tr>
<tr>
<td>Telescope B</td>
<td>1,001</td>
<td>1,075</td>
<td>105</td>
<td>2,181</td>
<td></td>
</tr>
<tr>
<td>Telescope C</td>
<td>416</td>
<td>(5)</td>
<td></td>
<td>411</td>
<td></td>
</tr>
<tr>
<td>Mountain Facilities</td>
<td>801</td>
<td>162</td>
<td></td>
<td>963</td>
<td></td>
</tr>
<tr>
<td>Staff Research</td>
<td>904</td>
<td>1,440</td>
<td>1,274</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Director's Office</td>
<td>208</td>
<td>221</td>
<td>422</td>
<td>843</td>
<td>1,693</td>
</tr>
<tr>
<td>Headquarters</td>
<td>382</td>
<td>892</td>
<td></td>
<td>1,274</td>
<td></td>
</tr>
<tr>
<td>Central Admin. Svcos</td>
<td>45</td>
<td>952</td>
<td>997</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Public Affairs/Outreach</td>
<td>93</td>
<td>893</td>
<td>986</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LSST</td>
<td></td>
<td>1,343</td>
<td></td>
<td>1,343</td>
<td></td>
</tr>
<tr>
<td>ETS Infrastructure</td>
<td>313</td>
<td>213</td>
<td></td>
<td>525</td>
<td></td>
</tr>
<tr>
<td>Data Products Program</td>
<td>332</td>
<td>140</td>
<td>1,200</td>
<td>1,672</td>
<td></td>
</tr>
<tr>
<td>NIO/GSMT</td>
<td>506</td>
<td>1,100</td>
<td>1,606</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Major Instrumentation</td>
<td>424</td>
<td>2,790</td>
<td>3,214</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Svc External Entities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AURA Support/Mgmt Fee</td>
<td></td>
<td>615</td>
<td>615</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL DIVISION</strong></td>
<td>3,772</td>
<td>6,291</td>
<td>1,156</td>
<td>12,784</td>
<td>24,003</td>
</tr>
<tr>
<td><strong>TSIP Funds</strong></td>
<td></td>
<td></td>
<td></td>
<td>$4,120</td>
<td>$4,120</td>
</tr>
<tr>
<td><strong>TOTAL NOAO Operational and TSIP Funds</strong></td>
<td></td>
<td></td>
<td></td>
<td>$28,123</td>
<td></td>
</tr>
</tbody>
</table>

FY05 Allocation Funding Only
CTIO column represents all funds for programs and operations in NOAO South
TSIP Annual funding includes estimated NOAO administrative costs.
### Table 3
NOAO FY06 Est. Funding Allocation
By Division and Program
Total = $31,536
(Dollars in Thousand’s)

<table>
<thead>
<tr>
<th>Program Area</th>
<th>KPNO</th>
<th>CTIO</th>
<th>NGSC</th>
<th>Tucson</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Ops/System</td>
<td>49</td>
<td>95</td>
<td>487</td>
<td>631</td>
<td></td>
</tr>
<tr>
<td>Instrument Upgrades</td>
<td>210</td>
<td>110</td>
<td>320</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer Infrastructure Support (CIS)</td>
<td></td>
<td></td>
<td>640</td>
<td>640</td>
<td></td>
</tr>
<tr>
<td>Telescope A</td>
<td>948</td>
<td>984</td>
<td>700</td>
<td>2632</td>
<td></td>
</tr>
<tr>
<td>Telescope B</td>
<td>811</td>
<td>874</td>
<td>700</td>
<td>2385</td>
<td></td>
</tr>
<tr>
<td>Telescope C</td>
<td>450</td>
<td>212</td>
<td></td>
<td>662</td>
<td></td>
</tr>
<tr>
<td>Mountain Facilities</td>
<td>992</td>
<td>955</td>
<td>1947</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff Research</td>
<td>45</td>
<td>60</td>
<td>50</td>
<td>1,004</td>
<td>1159</td>
</tr>
<tr>
<td>Director’s Office</td>
<td>392</td>
<td>388</td>
<td>800</td>
<td>1580</td>
<td></td>
</tr>
<tr>
<td>Headquarters</td>
<td>642</td>
<td></td>
<td>1,190</td>
<td>1832</td>
<td></td>
</tr>
<tr>
<td>Central Admin. Services (CAS)</td>
<td>540</td>
<td></td>
<td>1080</td>
<td>1620</td>
<td></td>
</tr>
<tr>
<td>Public Affairs/Outreach</td>
<td>6</td>
<td>150</td>
<td>985</td>
<td>1141</td>
<td></td>
</tr>
<tr>
<td>LSST</td>
<td>135</td>
<td></td>
<td>2000</td>
<td>2135</td>
<td></td>
</tr>
<tr>
<td>Data Products</td>
<td>135</td>
<td></td>
<td>1,400</td>
<td>1535</td>
<td></td>
</tr>
<tr>
<td>NIO/GSMT</td>
<td>520</td>
<td></td>
<td>1895</td>
<td>2415</td>
<td></td>
</tr>
<tr>
<td>Major Instrumentation</td>
<td>600</td>
<td></td>
<td>3,300</td>
<td>3900</td>
<td></td>
</tr>
<tr>
<td>Servicing External Entities</td>
<td>112</td>
<td>112</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AURA Support/Mgmt Fee</td>
<td>120</td>
<td>526</td>
<td>646</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$4,015</td>
<td>$6,400</td>
<td>$1,570</td>
<td>$15,307</td>
<td>$27,292</td>
</tr>
</tbody>
</table>

**TSIP Funds**

<table>
<thead>
<tr>
<th>TSIP Funds</th>
<th>$4,244</th>
<th>$4,244</th>
</tr>
</thead>
</table>

**TOTAL NOAO Operational and TSIP Funds**

<table>
<thead>
<tr>
<th>TOTAL NOAO Operational and TSIP Funds</th>
<th>$31,536</th>
</tr>
</thead>
</table>

*FY06 Allocation Funding Only*

*CTIO column represents all funds for programs and operations in NOAO South*

*TSIP Annual funding includes estimated NOAO administrative costs.*
Table 4
NOAO FY07 Est. Funding Allocation
By Division and Program
Total = $32,888
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Program Area</th>
<th>KPNO</th>
<th>CTIO</th>
<th>NGSC</th>
<th>Tucson</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Ops/System</td>
<td>51</td>
<td>100</td>
<td>790</td>
<td>941</td>
<td></td>
</tr>
<tr>
<td>Instrument Upgrades</td>
<td>216</td>
<td>232</td>
<td></td>
<td>448</td>
<td></td>
</tr>
<tr>
<td>Computer Infrastructure Support (CIS)</td>
<td></td>
<td></td>
<td>640</td>
<td>640</td>
<td></td>
</tr>
<tr>
<td>Telescope A</td>
<td>961</td>
<td>1,013</td>
<td>720</td>
<td>2694</td>
<td></td>
</tr>
<tr>
<td>Telescope B</td>
<td>852</td>
<td>900</td>
<td>720</td>
<td>2472</td>
<td></td>
</tr>
<tr>
<td>Telescope C</td>
<td>400</td>
<td>320</td>
<td></td>
<td>720</td>
<td></td>
</tr>
<tr>
<td>Mountain Facilities</td>
<td>1020</td>
<td>982</td>
<td></td>
<td>2002</td>
<td></td>
</tr>
<tr>
<td>Staff Research</td>
<td>46</td>
<td>62</td>
<td>60</td>
<td>991</td>
<td>1159</td>
</tr>
<tr>
<td>Director's Office</td>
<td>404</td>
<td>400</td>
<td>825</td>
<td>1629</td>
<td></td>
</tr>
<tr>
<td>Headquarters</td>
<td>670</td>
<td></td>
<td>1,230</td>
<td>1900</td>
<td></td>
</tr>
<tr>
<td>Central Admin. Services (CAS)</td>
<td>550</td>
<td></td>
<td>1,100</td>
<td>1650</td>
<td></td>
</tr>
<tr>
<td>Public Affairs/Outreach</td>
<td>6</td>
<td>155</td>
<td>952</td>
<td>1113</td>
<td></td>
</tr>
<tr>
<td>LSST</td>
<td>125</td>
<td>2000</td>
<td></td>
<td>2125</td>
<td></td>
</tr>
<tr>
<td>Data Products</td>
<td>150</td>
<td>1,600</td>
<td></td>
<td>1750</td>
<td></td>
</tr>
<tr>
<td>NIO/GSMT</td>
<td>535</td>
<td>1,829</td>
<td></td>
<td>2364</td>
<td></td>
</tr>
<tr>
<td>Major Instrumentation</td>
<td>625</td>
<td>3,500</td>
<td></td>
<td>4125</td>
<td></td>
</tr>
<tr>
<td>Servicing External Entities</td>
<td>116</td>
<td></td>
<td></td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>AURA Support/Mgmt Fee</td>
<td></td>
<td>125</td>
<td>544</td>
<td>669</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>$4,072</td>
<td>$6,819</td>
<td>$1,625</td>
<td>$16,001</td>
<td>$28,517</td>
</tr>
<tr>
<td><strong>TSIP Funds</strong></td>
<td></td>
<td></td>
<td></td>
<td>$4,371</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL NOAO Operational and TSIP Funds</strong></td>
<td></td>
<td></td>
<td></td>
<td>$32,888</td>
<td></td>
</tr>
</tbody>
</table>

FY07 Allocation Funding Only
CTIO column represents all funds for programs and operations in NOAO South
TSIP Annual funding includes estimated NOAO administrative costs
Table 5
NOAO Est. FY08 Funding Allocation
Total = $33,628
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Program/Division</th>
<th>KPNO</th>
<th>CTIO</th>
<th>NGSC</th>
<th>Tucson</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Science Ops/System</td>
<td>134</td>
<td>119</td>
<td>322</td>
<td></td>
<td>575</td>
</tr>
<tr>
<td>Instrument Upgrades</td>
<td>300</td>
<td>360</td>
<td></td>
<td></td>
<td>660</td>
</tr>
<tr>
<td>Computer Infra. Support</td>
<td>574</td>
<td></td>
<td>466</td>
<td></td>
<td>1,040</td>
</tr>
<tr>
<td>Telescope A</td>
<td>1,346</td>
<td>1,306</td>
<td>327</td>
<td></td>
<td>2,979</td>
</tr>
<tr>
<td>Telescope B</td>
<td>1,101</td>
<td>1,182</td>
<td>172</td>
<td></td>
<td>2,455</td>
</tr>
<tr>
<td>Telescope C</td>
<td>229</td>
<td></td>
<td></td>
<td></td>
<td>229</td>
</tr>
<tr>
<td>Mountain Facilities</td>
<td>891</td>
<td>178</td>
<td></td>
<td></td>
<td>1,069</td>
</tr>
<tr>
<td>Staff Research</td>
<td></td>
<td>1,282</td>
<td>100</td>
<td>1,210</td>
<td>2,592</td>
</tr>
<tr>
<td>Director's Office</td>
<td>229</td>
<td>243</td>
<td>464</td>
<td>1,147</td>
<td>2,083</td>
</tr>
<tr>
<td>Headquarters</td>
<td>420</td>
<td></td>
<td>981</td>
<td></td>
<td>1,401</td>
</tr>
<tr>
<td>Central Admin. Svces</td>
<td>50</td>
<td></td>
<td>1,109</td>
<td></td>
<td>1,159</td>
</tr>
<tr>
<td>Public Affairs/Outreach</td>
<td>102</td>
<td></td>
<td>1,118</td>
<td></td>
<td>1,220</td>
</tr>
<tr>
<td>LSST</td>
<td>100</td>
<td></td>
<td>2,028</td>
<td></td>
<td>2,128</td>
</tr>
<tr>
<td>ETS Infrastructure</td>
<td>344</td>
<td>234</td>
<td></td>
<td></td>
<td>578</td>
</tr>
<tr>
<td>Data Products Program</td>
<td>365</td>
<td></td>
<td>1,320</td>
<td></td>
<td>1,685</td>
</tr>
<tr>
<td>NIO/GSMT</td>
<td>557</td>
<td></td>
<td>1,987</td>
<td></td>
<td>2,544</td>
</tr>
<tr>
<td>Major Instrumentation</td>
<td>466</td>
<td></td>
<td>3,469</td>
<td></td>
<td>3,935</td>
</tr>
<tr>
<td>Servicing NSO</td>
<td></td>
<td></td>
<td>117</td>
<td></td>
<td>117</td>
</tr>
<tr>
<td>AURA Support/Mgmt Fee</td>
<td>117</td>
<td></td>
<td></td>
<td></td>
<td>117</td>
</tr>
<tr>
<td><strong>TOTAL NOAO Operational Funds</strong></td>
<td>4,347</td>
<td>7,648</td>
<td>1,297</td>
<td>15,834</td>
<td>29,126</td>
</tr>
<tr>
<td><strong>TSIP Funds</strong></td>
<td></td>
<td></td>
<td></td>
<td>$4,502</td>
<td>$4,502</td>
</tr>
<tr>
<td><strong>TOTAL NOAO Operational and TSIP Funds</strong></td>
<td>$33,628</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

FY08 Allocation Funding Only
CTIO column represents all funds for programs and operations in NOAO South
TSIP Annual funding includes estimated NOAO administrative costs
7 PERFORMANCE INDICATORS AND METRICS

As required under the Cooperative Agreement, NOAO reports annually on measurements of the Observatory’s performance; these metrics are periodically reviewed by the Program Review Panel. Although this would be more naturally part of the Annual Report than of the Long Range Plan, it is convenient at present to deliver these data here.

PUBLIC ACCESS AND OBSERVING SUPPORT

Telescope Subscription Rates

The telescope oversubscription rate is one salient measure of NOAO’s success in “providing forefront observing capabilities and observing support to U.S. scientists,” as mandated in the AURA/NSF Cooperative Agreement. An appropriate goal is to manage supply so that oversubscription rates lie in approximately the same range that NSF seeks to achieve in its grants program, i.e., with oversubscription between 2 and 3. It is noteworthy in Figure 1 that no dramatic change occurred in the 1-2 meter class with the introduction of SMARTS in 2003. The 8-m class rates include Keck, MMT, and HET time (under the TSIP Program for Keck and MMT and the previous NSF-supported program for public access to HET and MMT).

![Figure 1: NOAO Telescope Subscription Rates](image)

<table>
<thead>
<tr>
<th></th>
<th>00-A</th>
<th>00-B</th>
<th>01-A</th>
<th>01-B</th>
<th>02-A</th>
<th>02-B</th>
<th>03-A</th>
<th>03-B</th>
<th>04-A</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 m</td>
<td>6.8</td>
<td>5.0</td>
<td>4.1</td>
<td>2.4</td>
<td>4.8</td>
<td>3.1</td>
<td>3.0</td>
<td>2.7</td>
<td>2.5</td>
</tr>
<tr>
<td>4 m</td>
<td>3.0</td>
<td>2.8</td>
<td>2.4</td>
<td>2.9</td>
<td>2.0</td>
<td>2.8</td>
<td>2.6</td>
<td>2.8</td>
<td>2.5</td>
</tr>
<tr>
<td>1-2 m</td>
<td>1.9</td>
<td>1.5</td>
<td>1.7</td>
<td>1.7</td>
<td>1.3</td>
<td>1.2</td>
<td>1.4</td>
<td>1.4</td>
<td>1.5</td>
</tr>
</tbody>
</table>
Observing Programs Awarded Telescope Time on NOAO Telescopes

On an annual basis, approximately 400 observing proposals are awarded time on NOAO telescopes. In 2003, over 700 U.S. scientists and graduate students from 135 research institutions in 43 states were associated with these proposals, either as PI’s, Co-I’s, students, or other collaborators.

<table>
<thead>
<tr>
<th>FY03 Observing Programs</th>
<th>NGSC</th>
<th>KPNO</th>
<th>CTIO</th>
<th>HET/MMT</th>
<th>KECK</th>
<th>Total</th>
<th>Unique</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total U.S. observing programs awarded/scheduled time via TAC (12 mos. ending 7/31/03)</td>
<td>95</td>
<td>146</td>
<td>135</td>
<td>18</td>
<td>6</td>
<td>400</td>
<td>400</td>
</tr>
<tr>
<td>Subtotal U.S. thesis programs</td>
<td>11</td>
<td>36</td>
<td>25</td>
<td>4</td>
<td>1</td>
<td>77</td>
<td>77</td>
</tr>
<tr>
<td>Total U.S. investigators associated with successful proposals (excl. NOAO staff)</td>
<td>227</td>
<td>366</td>
<td>285</td>
<td>40</td>
<td>14</td>
<td>932</td>
<td>702</td>
</tr>
<tr>
<td>U.S. States (incl. D.C.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>43</td>
</tr>
<tr>
<td>[Unique] U.S. research institutions (excl. NOAO)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>135</td>
</tr>
</tbody>
</table>

Science Publications Based on Research at NOAO Telescopes

The scientific effectiveness of NOAO facilities is also measured by the number of papers published by scientists using data from NOAO telescopes, including the publications of U.S. scientists awarded time on the Gemini telescopes through the NOAO Gemini Science Center. The

Figure 2. Science Publications Using Data from NOAO Telescopes

Note: The apparent drop in number of papers in FY03 derives from the fact that beginning in FY03, we (correctly) excluded papers published by NOAO staff based on data from non-NOAO telescopes (e.g., HST).
number of papers published is shown below in Figure 2. This metric also includes papers deriving from public observing time awarded at the MMT and HET telescopes under a previous NSF-funded facilities instrumentation support program, and beginning in 2003, public access observing at the Keck and Magellan telescopes under the NSF-funded Telescope System Instrumentation Program (TSIP).

Citation Trends of Papers Using Data from NOAO Telescopes

How these papers have been cited in published papers is shown in the graph in Figure 3, which is based on our analysis of the NASA ADS database. As might be expected, recently published papers have had little time to attract citations. This is the cause of the ramp trend seen in Figure 3, as one can see by comparing the citation history of papers using HST data in Figure 4.
PUBLIC/PRIVATE PARTNERSHIPS AND COLLABORATIONS

Ongoing Partnerships: WIYN and SOAR

- WIYN is a corporation whose membership consists of the University of Wisconsin, the University of Indiana, Yale University, and NOAO. WIYN built and operates the 3.6-m telescope on Kitt Peak.

- The Southern Observatory for Astronomical Research (SOAR) telescope corporation is a consortium consisting of the University of North Carolina, Michigan State University, LNA Brazil, and NOAO. SOAR has completed a 4.2-m telescope on Cerro Pachón.


New Collaborations in 2003: The Thirty-Meter Telescope (TMT) consortium; University of Maryland partnership

Since WIYN and SOAR are the prototypes for the public-private partnerships envisaged in the decadal survey, the Program Review Panel is interested in measuring the university partners’ productivity with these facilities.
PUBLIC ACCESS TO THE GEMINI TELESCOPES AND THE TELESCOPES OF THE INDEPENDENT OBSERVATORIES

Number of Nights of Public Access
Provided by Gemini N. and S. and the Telescopes of the Independent Observatories
(Semesters 03A – 04B)

<table>
<thead>
<tr>
<th>Semester</th>
<th>Gemini</th>
<th>Keck, MMT, HET</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003A</td>
<td>74</td>
<td>27</td>
</tr>
<tr>
<td>2003B</td>
<td>81</td>
<td>29</td>
</tr>
<tr>
<td>2004A</td>
<td>128</td>
<td>19</td>
</tr>
<tr>
<td>2004B</td>
<td>140</td>
<td>25</td>
</tr>
</tbody>
</table>

ANALYZING, ARCHIVING, AND DISSEMINATING ASTRONOMICAL DATA

NOAO Science Archive Activity
FY02–03

<table>
<thead>
<tr>
<th>Activity/Year</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ingested</td>
<td>0.1 Tb</td>
<td>0.5 Tb</td>
</tr>
<tr>
<td>Downloaded</td>
<td>4.6 Gb</td>
<td>39.9 Gb</td>
</tr>
</tbody>
</table>

LEADERSHIP IN DEVELOPMENT OF NEW TELESCOPES, INSTRUMENTS, AND TECHNIQUES

Telescopes in Construction
- SOAR: Telescope mount tested; first instrument delivered and tested, AOS shipped

Telescopes in Design
- LSST and TMT: Proposals submitted and pending

Instruments Delivered
- GNIRS
Instruments in Design and Fabrication

- NEWFIRM, SOAR AO Module (SAM)

New Instruments Proposed

- ACES, KAOS

ACES is a concept for a Gemini HRNIRS (High resolution near infrared spectrograph.) KAOS is a concept for a Gemini WFMOS (wide field multi object spectrograph).

BUILDING THE INTEGRATED GROUND BASED / OIR SYSTEM OF PUBLIC/PRIVATE TELESCOPES

Telescope System Instrumentation Program (TSIP)

<table>
<thead>
<tr>
<th>TSIP PROGRAM</th>
<th>FY02</th>
<th>FY03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposals/Year</td>
<td>$ 7.2</td>
<td>$ 6.3</td>
</tr>
<tr>
<td>Funds Requested</td>
<td>$ 3.5</td>
<td>$ 3.6</td>
</tr>
</tbody>
</table>

Adaptive Optics Development Program (AODP)

<table>
<thead>
<tr>
<th>AODP PROGRAM</th>
<th>FY 03 Proposal Cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposals Received</td>
<td>17</td>
</tr>
<tr>
<td>Proposals Funded</td>
<td>6</td>
</tr>
<tr>
<td>Funds Requested</td>
<td>$ 10.0</td>
</tr>
<tr>
<td>Funds Awarded</td>
<td>$ 2.9</td>
</tr>
</tbody>
</table>
SUPPORT OF SCIENTIFIC STAFF WHO CONDUCT RESEARCH FOR ITS INTRINSIC VALUE

Publications and Citations

Under the terms of the Cooperative Agreement, NOAO is charged with conducting a broad program of research in astronomy and related fields for its intrinsic value and for the purpose of maintaining a staff that is scientifically productive and technically current. We measure the success of our scientific staff research by their annual publications rate and by the citation history of their publications. The publication rate is depicted in Figure 5. As shown in Figure 5, we track the science education publications of our outreach scientists separately.

![Figure 5](image)

Figure 5: Science and Science Education Publications of NOAO Scientific Staff

<table>
<thead>
<tr>
<th>Year</th>
<th>Tucson</th>
<th>NOAO S.</th>
<th>PAEO</th>
</tr>
</thead>
<tbody>
<tr>
<td>FY00</td>
<td>93</td>
<td>53</td>
<td>0</td>
</tr>
<tr>
<td>FY01</td>
<td>80</td>
<td>48</td>
<td>0</td>
</tr>
<tr>
<td>FY02</td>
<td>97</td>
<td>47</td>
<td>8</td>
</tr>
<tr>
<td>FY03</td>
<td>141</td>
<td>58</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 6 (below) is a convenient display of the career citations of the average NOAO scientific staff member. (The depiction of “negative” citations is an artifact of the graphics software.) It would be useful in future to provide some comparator data for a typical university department.
Value of Grants and Proposals (FY 2003)

Additional measures of NOAO staff leadership and service, both in science and in the community, can be broadly gauged by such criteria as the number and value of proposals and grants applied for, the prizes and awards accorded to NOAO staff members, invited talks, and service on national science committees. Data for FY 2003 are shown in the following table.

<table>
<thead>
<tr>
<th>Proposals</th>
<th>FY02</th>
<th>FY03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submitted to NSF</td>
<td>$1,640</td>
<td>$39,463</td>
</tr>
<tr>
<td>Submitted to NASA</td>
<td>$3,340</td>
<td>$2,953</td>
</tr>
<tr>
<td>Funded by NSF</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Funded by NASA</td>
<td>$692</td>
<td>$1,914</td>
</tr>
</tbody>
</table>
**FY03 Scientific Staff Service Activities and Invited Talks**

<table>
<thead>
<tr>
<th></th>
<th>FY02</th>
<th>FY03</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Committees</td>
<td>69</td>
<td>83</td>
</tr>
<tr>
<td>Invited Talks</td>
<td>73</td>
<td>75</td>
</tr>
</tbody>
</table>

**FY03 Scientific Staff Awards:** Malcolm Smith named *El Tiempo* “Personality of the Year”

**FY03 Diversity Metrics:** Under the Cooperative Agreement diversity metrics are reported separately to the National Science Foundation.
The NOA0 Astronomy Education and Training Programs

Support for U.S. Graduate Thesis Observing Programs

KPNO, CTIO, and the NOAO Gemini Science Center play a significant role in supporting U.S. graduate education in astronomy, not just by awarding telescope time to thesis programs through the TAC, but by providing travel and lodgings reimbursement for thesis students during observing runs.

Figure 7

Travel Support and Other Subsidies to Graduate Thesis Observers
(Dollars in Thousands)

<table>
<thead>
<tr>
<th>Semester</th>
<th>2002</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>KPNO</td>
<td>$25.0</td>
<td>$23.9</td>
</tr>
<tr>
<td>CTIO</td>
<td>$31.6</td>
<td>$30.0</td>
</tr>
</tbody>
</table>
Education Outreach and Teacher Training

- Number of teacher participants in NOAO’s TLRBSE and ASTRO programs: 288 (2003); 432 (2003)

Public Education and Media Outreach

- Press releases issued: 10 (FY02); 10 (FY03)
- AER Website: 150,000 hits and 6,000 separate visits from 5,500 separate sites per month.
- Revenue from Nightly Observing Program (NOP) and Advanced Observing Program (AOP): $255,000 in FY03 vs. $163,000 in FY02 (+56%)

Kitt Peak Visitor Center

<table>
<thead>
<tr>
<th>Summary</th>
<th>FY02</th>
<th>FY03</th>
<th>% Chg</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kitt Peak Visitors</td>
<td>50,000</td>
<td>70,500</td>
<td>+41%</td>
</tr>
</tbody>
</table>

**Detail FY03**

- Guided public tours*  10,546
- Self-guided tours     11,229
- School groups K-12   1,107
- Special tours         421
- Nightly Observing Program 7,017
- Advanced Observing Program 183
- General tourists-est. 40,000

Total (est.) 70,503

*Public tour data understated due to database malfunction in 2nd quarter*