The six Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT) enclosures at Cerro Tololo Inter-American Observatory. Each contains a single telescope optimized for specific bandpasses. PROMPT is a facility of the University of North Carolina (UNC) at Chapel Hill, P.I. Daniel Reichart, with primary objective of rapid and simultaneous multiwavelength observations of gamma ray burst (GRB) afterglows, followed by triggering of quick response observations at SOAR and Gemini South. PROMPT will also function as a platform for undergraduate and high school education throughout the state of North Carolina. Photo taken by Enrique Figueroa
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EXECUTIVE SUMMARY

NOAO has several reasons to remember 2005 as a gamma-ray “burster” of a year. First, Cerro Tololo Inter-American Observatory received a new array of six small automated telescopes (shown on the front cover of this Annual Report), called the Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT), which commenced science operations in 2005. Funded in part by the National Science Foundation, PROMPT is optimized to observe gamma-ray burst afterglows in six different colors. And second, the SOAR telescope, just a year after its dedication, detected the afterglow of the most distant gamma-ray burster yet seen (see page 5 of this report). Long duration γ-ray bursters, the most luminous objects in the Universe, will probably become essential probes of the epoch of reionization.

The γ-ray burster discoveries of the year, however, were the intermediate redshift identifications of short hard bursts GRB 050509B and GRB050709. The host galaxy of the latter was determined from spectroscopy with the Frederick C. Gillett Gemini North telescope to have a redshift of $z = 0.16$. This discovery connects the two classes of burster with different endpoints of stellar evolution. Short, hard, low luminosity bursts may signal the merger of two neutron stars/black holes, the fabled targets of gravity wave antennae.

In the decadal survey *Astronomy and Astrophysics in the New Millennium*, the Astronomy and Astrophysics Survey Committee identified the next generation of astronomical facilities and stressed that “effective national organizations are essential to coordinate, and to ensure the success and efficiency of, these systems.” These national organizations should work with the universities and independent observatories in developing the next generation of telescopes.” This is elaborated in a later chapter: “Community participation in major national telescope initiatives must be led by an effective national astronomy organization working in concert with universities and similar institutions. Such an organization should in turn be subject to close community oversight with appropriate advisory bodies. It should lead the development of a strategic plan [emphasis ours] for the evolution of the capabilities of the system by organizing discussions involving the NSF, the independent observatories, the academic community, and industry.”

In early 2005, the NSF charged NOAO with the task of plotting out a deliberate path—as opposed to a random walk—that would facilitate the development of decadal survey initiatives. In response, NOAO convoked a group representing the top-ranked specialist committees in the U.S. optical/infrared community. After a series of meetings and consultations, the O/IR Long-range Planning Committee, chaired by Caty Pilachowski of Indiana University, developed a road map for the O/IR facilities of the current decade, offering an extended view as far as 2025. Issued in July 2005, the Committee’s report, “Strategies for Evolution of U.S. Optical/Infrared Facilities” ([http://www.noao.edu/dir/lrplan/strategies-final.pdf](http://www.noao.edu/dir/lrplan/strategies-final.pdf)) was well received, and provides the community and the telescope projects with a firm basis on which to proceed, to compete, and to diverge or converge—without adding unplanned funding demands on NSF. It is probably no coincidence that the first designated NSF funding for the Design and Development Phases of GSMT and LSST arrived at AURA and NOAO shortly after the Long-range Planning Committee report was submitted.

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1 Board on Physics and Astronomy, National Research Council, 2001 *Astronomy and Astrophysics in the New Millennium: Panel Reports*
1.1 NOAO GEMINI SCIENCE CENTER

Gemini Near-Infrared Spectrograph Observations of the Central Supermassive Black Hole in Centaurus A

A team of U.S. astronomers, led by J. Silge and K. Gebhardt (U. Texas, Austin) studied the mass of the black hole in Centaurus A (NGC 5128) using the Gemini South telescope (2005, AJ, 130, 406). Centaurus A is the nearest galaxy that hosts an active galactic nucleus; it has an unusual morphology that is attributed to a recent merger. The correlation in bulge galaxies between central black hole mass, a local property, and velocity dispersion, a global property, helps advance our understanding of the formation and evolutionary histories of both the black hole and its host galaxy.

NGC 5128 contains large amounts of dust, which hampers optical spectroscopy. Optical spectroscopy is the traditional methodology for measuring the mass of the central black hole in bulge galaxies. Silge et al. measured the stellar kinematics of NGC 5128 using the Gemini Near Infrared Spectrograph (GNIRS) at Gemini South, employing the region around the CO band heads at 2.3 microns. The extinction in the K band is only 7% of that at B, allowing high quality spectra despite the substantial dust in NGC 5128. Thus, the ability to obtain high signal-to-noise spectra in the infrared, and the excellent image quality at Gemini South, strongly benefited this study.

Silge et al. derived a black hole mass of $2.4 \times 10^8$ $M_{\odot}$ for NGC 5128. This mass estimate is 5–10 times higher than that predicted by the correlation between black hole mass and velocity dispersion. In fact, NGC 5128 has the largest offset from the black hole mass vs. velocity dispersion relation of any galaxy yet measured. NGC 5128’s merger history is one avenue to possibly explain why its black hole mass is anomalously high relative to its velocity dispersion. In a merger, it is possible that the two central black holes merge relatively quickly, while it may take the merged galaxy significantly longer to attain its equilibrium dynamical configuration, presumably with elevated velocity dispersion.
Looking beyond NGC 5128, this team and others are targeting a number of important, but dusty, galaxies for central-black-hole mass measurements using Gemini South and GNIRS. Gemini South with GNIRS is poised to play a unique role in understanding the relation of central black hole formation to the formation and evolution of galaxies.

The Kinematics of Thick Disks in External Galaxies

Using the Gemini Multi-Object Spectrograph on Gemini-North (GMOS-N), P. Yoachim and J. Dalcanton (U. Washington) probed the kinematics in the thin and thick disks in two edge-on galaxies, FGC 227 and FGC 1415 (2005, Astrophysical Journal, 624, 701). GMOS-N was used in long-slit mode and centered on the Ca II infrared-triplet lines near 8500-8700 Å. This study benefited from the excellent image quality and accurate offsetting afforded by the Gemini telescopes.

Thick disks are common components of galactic types S0, Sb, and Sc and have global properties that are distinct from thin disks. In the Milky Way, the thick disk (first noted and studied by Gilmore and Reid 1983, MNRAS, 202, 1025) has a significantly larger scale height relative to the thin disk, rotates more slowly, and the thick-disk stars are generally more metal-poor and older than thin disk stars. An additional twist on the chemistry of Milky Way thick disk stars is that they tend to have alpha-enhanced elemental abundances when compared to thin disk stars of similar iron abundance.

Formation scenarios for thick disks tend to fall into three categories: in one case, the thick disk is formed from an initial thin disk that is heated by a minor merger event; in the second case, the thick disk is formed directly, perhaps as a result of monolithic collapse; a third scenario has a thick disk forming entirely outside of the eventual parent galaxy and then added as a result of a merger.

In the case of the two galaxies studied by Yoachim and Dalcanton, FGC 1415 has a thick disk that rotates at only 30–40% of the rotation speed of the thin disk, while the thick disk FGC 227 exhibits a rotation curve which is best modeled as a thick disk that is counter-rotating relative to its thin disk. Figure 2 shows the...
observed rotation curve of FGC 227 (bottom panel) and the model rotation curves (top panel) for thin (solid line) and thick (dashed curve) disks, respectively. With a best-fit model to the observed velocities that consists of counter-rotating systems, the GMOS-N observations provide strong constraints on the formation scenario for FGC 227. In this particular galaxy, such a configuration cannot result from the heating of a thin disk or monolithic collapse, but probably results from a merger, or accretion, of two distinct galactic systems.

Studies such as this one are facilitated by the excellent image quality provided by the Gemini telescopes. In addition, observations in the infrared, which can penetrate dust that often obscures the inner regions of galaxies, are useful; such possibilities are now provided by the GNIRS at Gemini South and the forthcoming addition of the Near-Infrared Field Spectrograph (NIFS) to Gemini North.

1.2 **Cerro Tololo Inter-American Observatory (CTIO)**

**The Most Distant Gamma Ray Burst (GRB)**

Observing on the SOAR telescope, the Gamma Ray Burst team led by D. Reichart (U. North Carolina) discovered the most distant GRB at \( z=6 \), smashing the previous distance record \( (z=4.5) \). Three hours after the detection of a faint but long-duration gamma-ray pulse GRB050904 by the satellite SWIFT, the 4.1-m SOAR telescope detected the afterglow with the infrared imager and spectrograph instrument OSIRIS. SOAR was the fourth telescope to target the coordinates of GRB050904, after the Spanish BOOTES (Burst Observer and Optical Transient Exploring System), the French TAROT (Télescope à Action Rapide pour les Objets Transitoires) project, and the Palomar 60” telescope. SOAR was the first to detect GRB050904 because the other telescopes were observing in the optical, whereas SOAR used the near-infrared window, detecting the GRB in the J band at \( J=17.4 \).

On the first observing night, SOAR photometry, coupled with the optical non-detections, ruled out the hypothesis that the very red visible to infrared color could be attributed to dust reddening, implying a very high redshift for the object consistent with the long duration outburst.
Measurements at SOAR in the Y,J,K bands on subsequent nights, coupled with the non-detection at shorter wavelengths from the PROMPT telescopes of UNC at Cerro Tololo, and other facilities, led to a photometric redshift of $z=6\pm 1$ by fitting the photometric spectral energy distribution to a model with negligible flux blueward of Lyman $\alpha$. The announcements in GCN3913, 3914, and 3919 called to the attention of the GRB researchers the importance of this burst and the biggest ground-based telescopes began immediately to observe GRB050904.

Further analyzing SOAR photometry, the Gemini detection in the z’ band, and photometry from other telescopes, Haslip et al. (2005 Nature submitted; astro-ph/0509660) determined a redshift of $6.39(\pm 0.11, -0.12)$, which is consistent with the reported spectroscopic redshift ($6.29 \pm 0.01$), confirming that this is the furthest-ever detected GRB and is among the furthest known objects ever seen.

The SOAR observations were led onsite by E. Cypriano (LNA, Brazil) and E. Figuerado. (See http://www.noao.edu/outreach/press/pr05/pr0509.html)

**Fundamental Plane Survey**

A comprehensive survey of more than 4000 elliptical and early-type galaxies has led to a conclusion opposite to what was expected from the most popular theory of galaxy formation. Contrary to expectations, the largest, brightest galaxies in the census consist almost exclusively of very old stars, with much of their stellar populations having formed as long ago as 13 billion years. There appears to be very little recent star formation in these galaxies, nor is there strong evidence for recent ingestion of smaller, younger galaxies. By contrast, the smaller, fainter galaxies studied by the NOAO Fundamental Plane Survey are significantly younger: their stars were formed as little as four billion years ago, according to new results from the survey team. The survey was conducted with the CTIO 4-m telescope and the WIYN 3.5-m telescope.

Led by M. Hudson (U. Waterloo, Ontario), the survey studied a sample more than five times larger than previous surveys. The results contrast sharply with the conventional hierarchical model of galaxy formation and evolution, in which large elliptical galaxies in the nearby Universe formed by swallowing smaller galaxies with young stars; this theory predicts that, on average, the stars in the largest elliptical galaxies should be no older than those in the smallest ones.

The evolutionary history of elliptical galaxies and lenticular galaxies (which have a central bulge and a disk, but no evidence of spiral arms) is not well understood. Their colors appear to be redder than typical spiral galaxies. The largest ellipticals are the reddest of all, but until this work it has not been clear whether this property results primarily from being older in age, as the survey found, or from having a higher proportion of heavy chemical elements (metallicity).

It was previously thought that all of the red galaxies were made of stars that formed very early and are now quite old. These results show that while this is true for the large galaxies, the smaller ones formed their stars comparatively recently in the history of the Universe. A simple prediction of this study is that as new surveys look deeper and further into the past, they should see fewer faint red galaxies.

**Low-luminosity, Compact Accretion Sources in the Galaxy**

Accretion onto compact stellar objects from companions in close binaries is the primary beacon for the study of the astrophysics of the extreme: from endpoints of stellar evolution to the processes in the extremes of gravity, radiation, and magnetic fields. However, the population of
even the most common accretion-powered compact objects—white dwarfs accreting from low-mass stellar companions known as cataclysmic variables (CVs)—has not been measured better than a factor of 10 in the solar neighborhood, and they have even a less-well known spatial distribution in the rest of the Galaxy.

J. Grindlay (Harvard and CfA) and collaborators have been carrying out the Chandra Multispectral Plane (ChaMPlane) Survey to measure the CV space density and X-ray luminosity functions, the CV population in the Galactic Center, the space density of quiescent low-mass X-ray binaries, and the population of high-mass X-ray binaries. Chandra is used to discover the objects, and follow-up is done with optical telescopes, principally the CTIO and KPNO 4-m telescopes with the Mosaic imagers, and the Hydra multi-fiber spectrograph on the Blanco 4-m. Ninety-four Chandra fields have been surveyed with 59 pointings (21 sq-deg) with the Mosaic imagers. The ChaMPlane Survey with the NOAO telescopes is part of the NOAO survey program.

Largest Known Stars in the Universe

Three red super-giants have been discovered that have the largest diameters of any normal stars known. A study, led by P. Massey (Lowell Obs.) and K. Olsen (CTIO), is significant in finally reconciling theory and observation for these stars. Red super-giants, massive stars nearing the ends of their lifetimes, are extremely cool and luminous, and very large.

The three stars with the largest known sizes are KW Sagittarii (distance 9,800 light-years), V354 Cephei (distance 9,000 light-years), and KY Cygni (distance 5,200 light-years), all with radii about 1500 times that of the Sun, or about 7 astronomical units (AU). For comparison, the red super-giant star Betelgeuse is known from other work to have a radius about 650 times that of the Sun, or about 3 AU. If one of these stars were placed in the sun’s location, its outer layers would extend to midway between the orbits of Jupiter (5.2 AU) and Saturn (9.5 AU). The previous record holder, mu Cephei comes in a close fourth in size in the study. The only other star for which a very large size has been claimed is the binary star system VV Cephei, which consists of a red super-giant and a hot companion orbiting within a common gaseous envelope, in which the gravitational forces of the companion have distended the surface of the super-giant and the meaning of the size of the star is therefore fuzzy. None of the stars in the new study are believed to be binaries, and thus their properties tell us about the extreme sizes that normal stars reach.

The study used the 1.5-m telescope at CTIO and the 2.1-m telescope at KPNO. The new observations were combined with state-of-the-art computer models that contain improved data on the molecules that are found in the outer layers of these cool stars. The analysis yielded the most accurate temperatures yet found for this type of object. The temperatures of the coolest red super-giants are about 3450K, or about 10 percent warmer than previously thought. Combined with modern estimates of the distances of these stars, the group was able to determine the stellar sizes as well.

The significance of this study is that for the first time in many decades there is good agreement on the theory of how large and cool these stars should be, and how large and cool we actually observe them to be. For the past two decades there has been a significant disagreement. The problem in this case turned out not to be the theory, but the conversion between the observed brightness and spectral type and the derived temperature and luminosity. The team’s new analysis provides a better means of converting between the observational and theoretical properties.
1.3 Kitt Peak National Observatory (KPNO)

You Cannot Hide from Spitzer and KPNO

Kitt Peak telescopes continue to be successfully used in conjunction with the leading space observatories to provide new insights on a wide range of astrophysical investigations. In particular, the wide-field optical imaging capabilities of the NOAO MOSAIC cameras have proven to be an invaluable complement to surveys from the Spitzer Space Telescope. Spitzer is a powerful and highly efficient tool for mapping wide swaths of the sky at mid- and far-infrared wavelengths. When combined with imaging data from KPNO, Spitzer observations have been able to identify populations of sources missed in the past because their optical emission is heavily obscured by dust. Further studies have led to the detection of polycyclic aromatic hydrocarbon molecules in high redshift, ultraluminous galaxies, the identification of luminous galaxies and quasars so heavily obscured by dust they are missing from deep optical surveys, and the discovery of a massive galaxy in formation.

Two recent studies, Houck et al. (2005, ApJ, 622, L105) and Yan et al. (2005, ApJ, 628, 604), have identified a number of sources that were bright at 24 µm, but very faint in corresponding KPNO 4-m optical images. Houck et al. selected objects within the NOAO Deep-Wide-Field Survey (NDWFS) Boötes field (Jannuzi & Dey 1999), which has extremely deep 3-band optical MOSAIC imaging, while Yan et al. investigated sources from the Spitzer First Look Survey, which also has publicly available KPNO 4-m imaging (Fadda et al. 2004, AJ, 128, 1). Roughly a third of these targets are invisible in the deep 4-m imaging (R > 26). Although these magnitudes would present a challenge even for spectroscopy with the largest ground-based telescopes, follow-up at 7–38 µm from the Spitzer Infrared Spectrograph measured redshifts for 17 sources in the Houck et al. study and six more in the Yan et al. program, nearly all in the redshift range 1.7 < z < 2.8. At these redshifts, their 24 µm fluxes imply that these are rare, hyperluminous (L_{IR} ~ 10^{13} L_{sun}) objects: truly needles in a haystack of millions of brighter optical galaxies, but identifiable by their unique optical-to-Spitzer color signatures. For the Yan et al. sample, the IRS spectra reveal strong PAH emission in some objects, suggesting the presence of massive star formation, although Houck et al. conclude that the majority of their sources are likely to be powered by active nuclei.

One particularly dramatic example selected from the Spitzer/NDWFS data was described by Dey et al. (2005, ApJ, 629, 654), who noted that its counterpart in the KPNO optical B_{W}-band imaging was a surprisingly large, diffuse blob. Follow-up Keck spectroscopy and narrow-band imaging from the WIYN Mini-Mosaic showed this “blob” to be diffuse Lyman-α emission at z = 2.66, extending over 20 arcsec (160 kpc). A few such “Lyman-α blobs” have been found previously, associated with a few powerful radio galaxies and high redshift proto-cluster environments, but their nature and significance remains puzzling. The inner regions of the Boötes blob show signs of orderly rotation, suggesting a very large kinematic mass (6 × 10^{12} M_{sun}). However, the source of ionizing energy capable of producing > 10^{10} L_{sun} of Lyman α emission remains a mystery. High-ionization lines of CIV and HeII in the central region suggest the presence of an active nucleus, and the 24 µm source itself is evidently hyper-luminous, but a careful study suggests that it cannot account for more than a fraction of the Lyman-α luminosity by itself. The authors suggest that this blob (and others) may mark the formation site for multiple galaxies and AGN within a dense local environment.
2.1 The Gemini Telescopes – NOAO Gemini Science Center

Support of U.S. Gemini Users and Proposers

The NOAO Gemini Science Center (NGSC) supports the U.S. community’s use of the state-of-the-art Gemini 8-meter telescopes. This support work includes informing the U.S. community of Gemini scientific observing opportunities, answering U.S. proposers’ and users’ queries, performing technical reviews of U.S. Gemini observing proposals, applying the NOAO TAC process to the U.S. Gemini observing proposals, interfacing with Gemini on the implementation of the selected U.S. Gemini proposals, providing assistance with and checking of the U.S. Phase-II submissions, and providing selected operational support to Gemini.

The NGSC saw a strong response from the U.S. community to the Gemini Call for Proposals for semester 2005B. On Gemini North for 2005B, 97 proposals were received: 50 for GMOS-North, 34 for NIRI, 14 for Michelle, and 7 for HIRES on Keck based on the Gemini time trade (some proposals requested more than one instrument). Ninety U.S. proposals requested Gemini South: 40 for GMOS-South, 28 for GNIRS, 15 for Phoenix, and 12 for T-ReCS. In total, the U.S. community proposed for 340.4 nights on the two Gemini telescopes.

The U.S. community responded enthusiastically to the Gemini Call for Proposals for semester 2006A. On Gemini North for 2006A, 106 proposals were received: 61 for GMOS-North, 36 for NIRI (12 of the NIRI proposals requested its use with the Altair adaptive optics system), and 17 for Michelle (some proposals requested more than one instrument). Ninety-four U.S. proposals requested Gemini South: 34 for GMOS-South, 23 for GNIRS, 21 for Phoenix, 14 for T-ReCS, seven for bHROS, and three for the Acquisition Camera. The oversubscription factors of 3.53 at Gemini North and 3.84 at Gemini South demonstrate healthy community engagement.

The Gemini observing process requires the submission of a Phase-II program once an observing program is approved. NGSC staff performed Phase-II reviews and related proposer interactions for U.S. Gemini proposals. Because the Phase-II submission must describe an observation completely and conform to numerous rules and conventions, few users submit a correct Phase-II initially. Usually, multiple iterations and communications with the PI are required.

NGSC organized a booth for the San Diego AAS meeting in January 2005. The booth featured displays on how to propose for Gemini observing opportunities, brochures on available Gemini instruments, and tutorials on preparing Phase-II programs. Numerous community members visited the NGSC booth.

The NGSC booth was the site of enthusiastic discussions with the community at the January 2005 AAS meeting in San Diego.
In order to see the powerful capabilities of GNIRS on Gemini South exploited for major scientific initiatives, NOAO is conducting a pilot program to enable observations with high scientific potential that require significant blocks of time. This “GNIRS Key Science Opportunity” was initiated for semester 2004B and continued in semesters 2005A and 2005B. In order to help inform the community, NGSC created a Web site on the GNIRS Key Science Opportunity and also publicized the opportunity in the NOAO/NSO Newsletter. NOAO selected the following programs for GNIRS Key Science: “A Near-Infrared Kinematic Survey of Nearby Galaxies: Black Holes, Bulges, and the Fundamental Plane” by Karl Gebhardt (U. Texas) and colleagues and “A GNIRS Survey of Massive Galaxies at z~2.5: Stellar Populations, Kinematics, and Scaling Relations in the Young Universe” by Pieter Van Dokkum (Yale U.) and colleagues.

NGSC provided observing support and maintenance of the NOAO-built Phoenix high-resolution infrared spectrograph on Gemini South. NGSC staff members V. Smith, K. Hinkle, R. Blum, et al. provided Phoenix user support at Gemini South for community science programs during FY 2005. NGSC regularly sends staff to the Gemini telescopes to provide assistance with queue observing and for training on Gemini observing procedures. Witnessing firsthand how the Gemini telescopes, instruments, and queue observing function is essential to supporting the U.S. community. NGSC staff have also participated in instrument commissioning and system verification at the Gemini telescopes. In FY05, NGSC staff helped support 174 nights of observing and/or testing at the two Gemini telescopes.

Providing U.S. Scientific Input to Gemini

The U.S. Gemini Science Advisory Committee (SAC), which serves as NGSC’s community-based advisory committee, met by teleconference and had numerous e-mail discussions during FY 2005. T. Armandroff briefed the committee on the status of the Gemini telescopes and instruments, the U.S. instrumentation effort, and current scientific and technical issues. The U.S. Gemini SAC discussed the current state of observing capabilities on Gemini, future opportunities, and how the priorities of the U.S. Gemini community should be enunciated. Membership of the U.S. Gemini SAC is described at www.noao.edu/usgp/staff.html. Six members from this group participated in the Gemini Science Committee meetings in Waikoloa, Hawaii on October 12-14, 2004 and April 21-22, 2005. T. Armandroff represented the United States at the Gemini Operations Working Group meetings in February 2005 in La Serena, Chile and in August 2005 in Oxford, United Kingdom.

U.S. Gemini Instrumentation Program

One component of the U.S. Gemini Instrumentation Program consists of instruments being built or designed by NOAO for use on Gemini. Such NOAO-enabled projects are described below in the Major Instrumentation Program section of this report.

The other class of U.S. Gemini instruments consists of those being built at other U.S. institutions under an AURA contract awarded by NOAO, with NGSC technical and managerial oversight. Progress on two such instruments is described below.

- **NICI**, the Near Infrared Coronagraphic Imager, will provide a 1- to 5-micron dual-beam coronagraphic imaging capability on the Gemini South telescope. Mauna Kea Infrared (MKIR) in Hilo is building NICI, under the leadership of D. Toomey. During FY 2005, the NICI team achieved the following major milestones: successful integration of the major components of the instrument; installation and successful testing of the optics in the NICI dewar, leading to outstanding optical performance; successful read-out of the two ALADDIN array detectors in NICI by the NICI
electronics, which are performing near specification; and successfully interfacing the NICI high-level software with the NICI arrays/controllers, motors, and temperature sensors. At the close of FY 2005, the final integration of the NICI adaptive optics system was underway, with all adaptive optics components delivered or shipped to MKIR. By the end of FY 2005, MKIR reported that approximately 98% of the work to NICI final acceptance had been completed. NICI is expected to be deployed on Gemini South in semester 2006A.

- **FLAMINGOS-2** is a near-infrared multi-object spectrograph and imager for the Gemini South telescope. FLAMINGOS-2 will cover a 6.1-arcminute-diameter field at the standard Gemini f/16 focus in imaging mode, and will provide multi-object spectra over a 6.1\(\times\)2-arcminute field. It will also provide a multi-object spectroscopic capability for Gemini South’s multi-conjugate adaptive optics system. The University of Florida is building FLAMINGOS-2, under the leadership of PI S. Eikenberry. In FY 2005, the FLAMINGOS-2 team was in the fabrication phase and then transitioned to the integration/test phase. FLAMINGOS-2 achieved the following major milestones: testing and acceptance of all optics for the imaging mode of FLAMINGOS-2; testing and acceptance of the FLAMINGOS-2 On-Instrument Wavefront Sensor (OIWFS); integration of most components into the instrument; successful cold and vacuum testing of the two FLAMINGOS-2 cryostats; and reading out the detector multiplexer. At the close of FY 2005, approximately 84% of the work to FLAMINGOS-2 final acceptance had been completed.

### 2.2 CTIO Telescopes

FY05 efforts were concentrated in three areas: (1) integration and commissioning the SOAR telescope and its instruments, (2) operating the Blanco telescope with a suite of wide-field instruments, and (3) advancing the Dark Energy Survey (DES) project, following selection of a Fermilab-led consortium to build a new, very wide-field camera for the Blanco telescope. CTIO also facilitated the installation of two new instruments on the 1.5-m and 1.0-m telescopes for the SMARTS consortium.

**Blanco 4-m Telescope**

The wide-field IR imager NEWFIRM, to be shared between the Mayall and Blanco, should be delivered early in 2007 and re-located to the South in 2008 or 2009. Progress was made on the several fronts relating to the DES project, which plans to conduct a five-year imaging survey on the Blanco telescope starting in 2009, using 30% of the observing time for five years to carry out a four-pronged project to study dark energy. The 500 Gpixel CCD camera and its data system, to be provided by the consortium, would also be available as a facility instrument for NOAO users. In FY05, the consortium was enhanced by the addition of the University of Michigan as well as international partners from the U.K. and Spain, bringing strong technical and scientific expertise to the effort. Progress was made on design of the instrument and data system, and in particular the early foundry runs of the LBL high-resistivity CCDs appear to have been successful. The DES requires a well-behaved and stable telescope point-spread function; thus a project to understand the support system of the Blanco primary mirror was initiated, with a view to improving the lateral support system that has been trouble-prone since the telescope was built. In addition, an FEA analysis was made of the telescope structure to facilitate the design of the support system for the camera and optics, which includes building a new prime focus cage. The U.S. and U.K. Dark Energy Task Force committees are evaluating the scientific priority of near-term dark energy projects, such as the DES, given the major LST and JDEM projects planned for the next decade, which will provide tight constraints on cosmological parameters.
High priority for the near-term projects will be a prerequisite for DOE and PPARC approving funding for the Dark Energy Camera.

Southern Astrophysical Research (SOAR) Telescope

CTIO completed delivery of the two Nasmyth focus instrument support adaptors and calibration systems, and the two CTIO-supplied instruments, the Optical Imager and the Ohio State University IR imaging spectrometer OSIRIS, were commissioned and are in regular use for early science programs. These are scheduled each dark-of-the-Moon period for approximately 25% of the time. CTIO staff worked to commission other major sub-systems, such as the tertiary-mirror tip-tilt assembly, and the University of North Carolina Goodman Spectrograph. The poorly performing primary-mirror lateral link system was carefully analyzed; the necessary repairs are substantial and require replacement of the supplied passive link system with all-new hardware and active control. The SOAR partners (Brazil, Michigan State University, and the University of North Carolina) raised significant capital, and NOAO committed substantial in-kind labor for the re-work, which should be completed early in FY06. However, as a consequence, the early-science phase of operation has been extended, and ramp-up to full operations is now planned for semester 2006B.

SMARTS Consortium and Other Small Telescopes

The Small and Moderate Aperture Telescope Research System (SMARTS) consortium entered year three of the three-year project. NOAO users averaged 27% of the time on the 0.9-m, 1.0-m, 1.3-m, and 1.5-m telescopes over the course of FY05. The CCD imager built by Ohio State University for the 1.0-m telescope was initially fitted with a 512 CCD; this was replaced with a thinned Fairchild CCD with excellent blue and UV-performance towards the end of FY05. The deployment of the University of Montreal 2K IR Imager on the 1.5-m occurred in January 2005, more than a year later than expected due to delays in completion of the instrument. The imager has a 30 arc minute wide field, and provides a unique survey capability. Most of the time in FY05 was used to carry out a galactic plane survey for Wolf-Rayet stars, by SMARTS partner, the American Museum of Natural History (AMNH). There is strong interest among consortium members in renewing the present agreement (i.e., SMARTS II) after its expiration in January 2006.

The University of North Carolina Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT) project consists of six small telescopes that rapidly follow-up gamma-ray bursts discovered by the SWIFT satellite and subsequently trigger a target-of-opportunity interrupt at SOAR. At other times, the telescopes will make observations as part of an extensive education and outreach program in North Carolina. The initial suite of telescopes was installed in FY05, with full operation due to begin in January 2006. Several successful GRB follow-up observations were made during the commissioning period.

U.S. institutions operate two other telescopes on Cerro Tololo. The 0.6/0.9-m Curtis Schmidt telescope is operated by the University of Michigan, now open part-time in a NASA-funded project to catalog space debris in geosynchronous orbits. The 0.4-m Lowell telescope remains closed to general users, although it is occasionally operated by the Lowell Observatory. Discussions were held with several other U.S. institutions regarding siting of facilities on Cerro Tololo.
Blanco Instrumentation

- **Mosaic 2**: The Mosaic imager at prime focus continues to be the most popular Blanco instrument, being scheduled for just under 50 percent of the observing time. In FY05, maintenance was carried out on the filter track assembly to replace parts worn out after over five years of heavy use.

- **ISPI**: The Infrared Side Port Imager is presently the widest field large-telescope IR imager in the Southern hemisphere, covering 11 arc minutes square with 0.33 arc second per pixel sampling at 1–2.4 microns. This complements the small-field, high angular resolution near-IR imaging capability soon to be available at SOAR, and the infrared spectroscopic instrumentation, GNIRS, and T-Recs, at Gemini South. Following commissioning of ISPI in FY03, the instrument was heavily scheduled in FY05 for a variety of survey and targeted programs.

- **HYDRA-CTIO**: HYDRA is the third Blanco wide-field instrument; it can be installed permanently together with Mosaic and ISPI. It had an extensive upgrade in FY03; further attention to reliability issues in FY05 has apparently reduced the downtime of this complex instrument to the level of ISPI and Mosaic.

- **RC Spectrograph**: This spectrograph, still very popular, was scheduled in severely blocked mode in FY05. The Loral 3K CCD suffered some deterioration in performance, with highly elevated dark count. Changing operating parameters alleviated this, allowing near-normal performance for most science programs, but there is concern as to the longevity of the CCD, for which no spare is available. The RC spectrograph is to be retired when the SOAR Goodman spectrograph enters full operation, not expected until semester 2006B.

- **Echelle Spectrograph**: This instrument has been retired to reduce the staff support load, given its lower demand compared to other Blanco instruments. There is no direct replacement available for U.S. observers in the Southern hemisphere until STELES on SOAR is completed in 2007–2008. Until then, a small amount of TSIP time is available with MIKE on Magellan, and some programs will be possible using bHROS on Gemini-S.

SOAR Instrumentation

- **Optical Imager**: Built at CTIO, this instrument was regularly used on SOAR for commissioning and early science activities in FY05. The instrument has performed well in these tasks, a few modifications, principally to change IR-light emitting encoders and to install extra baffles, were made in the course of this work.

- **OSIRIS**: The Ohio State Infrared Imager and Spectrometer, which is fitted with a CTIO 1K × 1K Rockwell HgCdTe array, was moved to SOAR after several years of use on the Blanco telescope and successfully commissioned in FY05. It provides modest-resolution near-infrared spectroscopy (up to R=3000) for the NOAO and SOAR community. Apart from commissioning the “IR” Nasmyth focus of SOAR, OSIRIS was used to conduct early science operations, which included the highly-publicized early observations of the most distant (z=6.3) gamma ray burster remnant.

- **Other SOAR Partner Instruments**: CTIO is building dewars and integrating the CCD focal planes for both the University of North Carolina Goodman High-Throughput Spectrograph and the University of Sao Paulo Integral Field-Unit Spectrograph. Three Lincoln Laboratory CCDs
of the six expected were delivered in FY05; there are likely to be no more received from a
disappointing foundry run. The measured quantum efficiency of the CCDs is lower than
expected; however, they have been installed, and commissioning of the spectrograph is
proceeding with a view to undertaking some early science programs in semester 2005A.

2.3 KPNO TELESCOPES

FY05 saw major work on all of the KPNO telescopes as well as significant progress on
developing new instruments for the observatory. For WIYN, highlights include the successful
installation and commissioning of a new fiber positioner for Hydra and the award of funding for the
QUOTA and ODI instruments. The Mayall 4-m primary mirror was aluminized and the NASA
Goddard Space Flight Center and Space Telescope Science Institute successfully commissioned their
IR Multi-Object Spectrograph at the 4-m. Major repair work was completed on the 2.1-m, as well as
continued progress in the development of the high-precision radial velocity spectrograph, the
Exoplanet Tracker, for use at the 2.1-m and Coudé Feed. The battle to preserve dark skies continued
in the local political arena.

WIYN 3.5-m

Over the course of FY05, a team led by P. Knezek (WIYN) completed worked on the fabrication
and integration of a replacement for the Hydra fiber positioner. Some key components of the
original positioner could no longer be replaced, leading to the risk of catastrophic failure. In
addition, several improvements had been made to the design when implementing Hydra II for
CTIO, which were desirable upgrades for WIYN performance. In the course of testing and
commissioning the new positioner, the control software and model for placement of the fibers have
both been improved, yielding fiber positioning accuracy better than at any time in the history of
the instrument. We estimate that the new system has added at least 10 years to the effective
lifetime of the instrument.

Also in FY05, work continued to upgrade the Bench Spectrograph (part of Hydra). Led by D.
Harmer (KPNO) and M. Bershady (U. Wisconsin), this major upgrade to improve system
throughput and sensitivity is scheduled to be completed in FY 2006.

Major progress was made toward completing two new imagers for WIYN, QUOTA and
ODI. Both will use the new technology devices with zonal fast guiding on-chip being developed
by WIYN Director G. Jacoby in a collaboration with J. Tonry and the PanSTARRS group at U.
Hawaii. These orthogonal transfer arrays of CCDs will enable superb delivered image quality over
a wide field. A combination of WIYN partner funding and awards from the NSF (ATI and TSIP
programs) have provided the funding necessary to deploy QUOTA in 2006 and ODI in 2009.

Upgrades to the WIYN azimuth and elevation drives were begun in FY 2005 and should be
completed in early FY06, providing improved performance and longer lifetimes for these important
components of the telescope that had seen significant wear during the lifetime of the observatory. A
new design for the tertiary locking mechanism has also been completed and is ready for PDR.

Mayall 4-m

During a late summer shutdown of the Mayall, the primary and secondary mirrors were success-
fully given new aluminum coatings. The radial and axial supports for the primary mirror were
repaired and refurbished. We installed new upgraded absolute encoders for both the R.A. and
declination axes. This work was done to enable the telescope to continue to deliver the excellent data sets it has been producing in recent years. The control room was provided with some new computer monitors and non-static carpeting to improve the workspace for the astronomers and OA.

J. MacKenty (STScI) continued to commission the IR Multi-Object Spectrograph (IRMOS) on the 2.1-m and Mayall 4-m telescopes. IRMOS was produced for KPNO by STScI and the James Webb Space Telescope (JWST) project at Goddard Space Flight Center. The instrument employs a commercial digital micro-mirror array as a cold, programmable multi-slit mask. KPNO fabricated the optical bench and designed and fabricated the telescope mounting interfaces and handling cart. The instrument has now had several successful engineering observing runs and in FY05 was exercised for the first time on the 4-m. This required the construction of a new interface adaptor, a new handling cart, and other modifications to ease use of the instrument at the 4-m. The instrument control system allows the user to image a field, design a slit configuration from the new image, dial in the grating of choice, and immediately take multi-object near-IR spectra. We have accepted our first round of public proposals for this instrument (successful proposals will be scheduled during semester 2006A) and anticipate successful science observations by the general community in the future.

Work continues on the 4-m in preparation for the arrival of the wide-field near-IR imager NEWFIRM in late 2006. This new instrument will bring a powerful near-IR survey capability to NOAO’s 4-m telescopes. To mount this large instrument on the Mayall requires a new Cass Cage bottom to be constructed as well as the fabrication of a handling cart for installing the instrument on the telescope. KPNO engineering also were heavily involved in the design, fabrication, and testing of the guider for NEWFIRM. We look forward to NEWFIRM commissioning runs at the end of FY06 or early FY07.

2.1-m

The 2.1-m was in need of major repairs to the telescope control cabling. This work was completed during summer shutdown, but since the replacement cables came from the same spool that provided the cables that failed, we will monitor the status of the replaced cable to make sure that future wear does not result in failure of the control system.

J. Ge and his University of Florida colleagues had several successful science runs with their innovative high precision radial velocity fiber-fed bench spectrograph. The optics project a fringe pattern from a Michelson interferometer at nearly right angles to the absorption features on the widened stellar spectrum. The recorded phase of the interference fringes is then extremely sensitive to small velocity shifts. The Florida team have been able to obtain 3.5 m/s repeatability, following a series of upgrades that provided significantly improved thermal stability. Very high throughput was achieved by acquisition of a larger diameter collimator and by implementing both beams of the interferometer. Use of the instrument on the 2.1-m now provides stable measurements on stars of 8th and 9th magnitude. The next step in improving long-term stability is to provide an interferometer with full passive thermal compensation, very similar to the design used in the GONG network. The intention is to make the Exoplanet Tracker available to NOAO visiting astronomers starting with the 2006B semester. The first results from the Ge et al. search for planets will be announced at the January 2006 AAS meeting.

VERITAS Project

Because of site approval difficulties near Mt. Hopkins, Kitt Peak was chosen as the site for the Very Energetic Radiation Imaging Telescope Array System (VERITAS) project. The scientific goal of VERITAS is to detect and characterize the extremely high energy gamma rays that are produced by quasars, supernova explosions, and other compact objects by the optical flashes emitted when the
gamma-ray photons smash into the Earth’s atmosphere. This project, which received high priority in the astronomy decadal survey, is led by Smithsonian Astrophysical Observatory (PI T. Weekes), and includes a consortium of universities: Purdue, Iowa State, Washington at St. Louis, Chicago, Utah, UCLA, McGill, Dublin Ireland, and Leeds in the U.K. The U.S. partners are funded by the Smithsonian Institution, DOE, and NSF.

The observatory will ultimately consist of seven 12-m (36-foot) optical imaging telescopes, each with 315 mirror segments, and a 3.5-deg field of view. The final array configuration is planned to be a filled hexagon with sides of 265 feet. The initially funded configuration consists of four telescopes. The telescope array does not need access to the horizons but does need protection from ground-level lights. The project identified a bowl area just above our Kitt Peak “lake” suitable for placing the telescopes, support structures, and control building.

After receiving approval to sub-lease a dedicated site of ~20 acres and beginning site preparation and telescope construction, work was halted by the NSF and DOE in summer, 2005 in voluntary response to a subsequently dismissed lawsuit by the Tohono O’odham Nation requesting a halt to construction. The NSF has decided to have a new Environmental Assessment and a Cultural Resources Report prepared, and is reconsidering final site selection for VERITAS.

Site Protection

The rapid growth of the Tucson metropolitan area requires a proactive approach to minimize the impact of light pollution on the operation of the observatory. In FY05, the KPNO Director, R. Green, and Deputy Director, B. Jannuzi (now Acting Director), made appearances at various government meetings to speak on behalf of protecting the night skies with enforcement of existing lighting codes. Jannuzi was appointed by the City of Tucson and Pima County to their respective Outdoor Lighting Code Committees. In 2005, KPNO also opposed attempts at the state government level to remove the ability of local governments to regulate outdoor lighting. While some potentially harmful legislation was passed by the legislature, the Governor vetoed the threatening bills.

In FY05, the major issue in light pollution has been with Pima County and its attempt to settle disputes with the billboard industry over numerous violations of County code. The KPNO Director was asked by the County Board of Supervisors to serve on a Citizen’s Advisory Committee to develop terms for a settlement that represented astronomy and community interests. The goal is to gain long-term acceptance by the billboard industry of the principle that the County and State have authority to regulate; the benefit will be voluntary compliance with light pollution control ordinances, which will be very effective when observed. The Acting KPNO Director will continue KPNO’s representation in this on-going process.

2.4 Community Access to the Independent Observatories

NOAO continues to coordinate the time allocation (TAC) process for telescope time that is made available to the broad community on the large, private telescopes through the Telescope System Instrumentation Program (TSIP) and its predecessor, the Facility Instrumentation Program (FIP).

MMT Observatory and the Hobby-Eberly Telescope

In the late 1990s, NSF’s Facility Instrumentation Program granted instrument funds to groups associated with the Multiple Mirror Telescope (MMT) and the Hobby-Eberly Telescope (HET). In return, the MMT Observatory agreed to schedule 162 nights at a nominal rate of 26 nights per year
and the HET agreed to carry out observations equivalent to 101 clear nights at a nominal rate of 17 nights per year for telescope programs approved by NOAO’s Time Allocation Committee (TAC). NOAO’s role in this program is limited to the time allocation and community interface activities.

In the 2005A/B semesters, NOAO received 18 proposals for time on the MMT, with requests totaling 48 nights. Overall, this amounts to an oversubscription rate of about 2.8. Eight of these 18 proposals were granted time.

Fifteen proposals for time on the HET were received in the two 2005 semesters, requesting a total of 31.3 nights. This amounts to an oversubscription rate of about 1.7 over the time available. Thirteen of these proposals were granted some or all of the time requested.

### Keck and Magellan Telescopes

NOAO’s role in TSIP includes not only the distribution of telescope time, but also the management of the annual TSIP proposal peer-review process and oversight of the instrument development activities of successful proposers. Those aspects of the program are discussed in Section 4.4 of this Annual Report.

In both 2005 semesters, time from TSIP awards was available to the community on the Keck and Magellan telescopes. In 2005A, four nights were available on each of the Keck 10-m telescopes. In that semester, a total of 36 proposals requesting 63.5 nights were received. The resulting oversubscription rate was about 8. Five of these observing proposals were granted time on one of the Keck telescopes.

In the two 2005 semesters, three nights were available on the Magellan I telescope and four nights on the Magellan II telescope. NOAO received 12 proposals requesting a total of 28 nights, an oversubscription rate of 4. Three of these proposals were granted time.

### 2.5 Joint NOAO-NASA Time Allocation

NOAO has organized several ad hoc programs to address the needs of projects that require time on ground-based telescopes associated with observations made on one of NASA’s Great Observatories (Chandra, HST, and Spitzer). The goal of these arrangements is to eliminate the double jeopardy of two peer reviews for proposals that require both sets of observations to accomplish their objectives. In FY 2005, one HST proposal and four Chandra proposals were approved for NOAO observations. With the successful initiation of Spitzer operations, a similar arrangement has been negotiated with the Spitzer Science Center, starting with cycle 2 of their General Observer program.

### 2.6 NOAO Survey Programs

The NOAO Survey Program has been very successful, with 15 surveys undertaken since inception in 1999. The surveys tend to be multi-year projects and often are aimed at generating complete data sets. In 2003, it was realized that NOAO should make an effort to adjust its allocation of telescope time to accommodate weather and instrumental problems that survey projects have encountered in order to improve the chances of success. Consequently, no new survey proposals were solicited in 2003 or 2004. Instead, the annual meeting of survey PIs was held with the survey panel of the NOAO TAC as audience, and the PIs were asked to address the needs of their surveys for supplemental telescope time.

In January 2005, the AURA Observatories Council reviewed the survey program and endorsed its continuation. New survey proposals were solicited to start in the 2005A semester.
Fourteen proposals were submitted and three were approved. The surveys selected are “A Census of the High Redshift Radio Universe,” (PI: A. Connolly, U. Pittsburgh); “Optical Follow-up of the XMM Cluster Survey: The XCS-NOAO Survey,” (PI: C. Miller, NOAO); and “SZE+Optical Studies of the Cosmic Acceleration,” (PI: J. Mohr, U. Illinois).

2.7 NOAO DATA PRODUCTS PROGRAM

Following the launch of the NOAO Science Archive (NSA) in mid-2002, the Data Products Program has focused on the development of an integrated data management and processing system that will provide efficient access to NOAO data and data products by the astronomical community. The short-term goal of the program is to move from the current archive holdings—limited to data products provided by the survey teams—to the storage of all raw data from all NOAO facilities, together with the pipeline reduction of a substantial fraction of those data. The intent is to provide a new channel for access to data by making data available to the community after a proprietary period, and also to assist observers by providing a simple way to download raw or reduced data following observing runs. This end-to-end system thus provides data transport, data safe store, and data access, and will be compatible with standards, interfaces, and tools that are being developed by the National Virtual Observatory (NVO) effort. This is a large undertaking and only the first pieces were in place at the end of FY 2005.

Work on the NSA in FY05 focused on design and development of Release 3, which is scheduled for FY06. This will be the release at which the “interim” NSA, put in place to serve the NOAO survey program data to the community, will be replaced by a carefully engineered, scaleable archive into which data from all NOAO telescopes and instruments will flow. The user interface of the NSA has been split off as a separate project, with the intent of utilizing Virtual Observatory protocols to enable a general purpose portal that will provide access to data and tools, both internal and external. A prototype of the NOAO VO portal is planned for release in early 2006.

Work on data reduction pipelines has moved from its early focus on the CCD mosaic imagers to NEWFIRM, the wide-field near-IR imager that is now under construction. This development is being undertaken with the assistance of two personnel from the University of Maryland, a scientist and a software developer. The first release of the NEWFIRM pipeline, to support commissioning of that instrument, is scheduled for early 2006.

The data transport has been in operation since August 2004, and the old tape-based Save-the-Bits program has been discontinued. Raw data repositories are currently maintained in La Serena, Tucson, and at the National Center for Supercomputing Applications (NCSA). The Data Products Program staff completed work on the Gemini IRAF development as part of a joint Gemini-NOAO effort.
3.1 **GEMINI INSTRUMENTS**

**Gemini Near-Infra-Red Spectrograph (GNIRS)**

The largest instrument project ever undertaken by NOAO, the Gemini Near-InfraRed Spectrograph (GNIRS), now provides the Gemini South telescope with long-slit capabilities at a range of dispersions through selectable gratings, covering the wavelength region from 0.9 micron to 5.5 microns at two pixel scales, by means of interchangeable cameras that feed a single 1024 pixel square ALADDIN-type InSb detector. It also provides options for 0.9–2.4 micron cross-dispersion, polarization analysis, and an integral field unit.

The project team, under the leadership of Project Scientist J. Elias, delivered the instrument to Cerro Pachón on October 31, 2003. GNIRS was installed on Gemini South, and commissioning was completed by mid-2004. GNIRS began actively serving the Gemini science community in Semester 2004B.

From June–August of 2005, NOAO personnel visited Gemini South to assist Gemini staff in a major service mission. Project Scientist J. Elias and Senior Instrument Technician R. George each spent more than ten weeks in Chile. They also took with them a number of tools and other equipment to assist the effort. They and the Gemini staff replaced two out-of-specification lens elements in the short focal length cameras, investigated and resolved several minor mechanical problems with the grating and prism turrets, installed some new filters, and improved the electrical grounding to reduce detector noise.

**Gemini Next-Generation Instrument Design and Feasibility Studies**

Following its summer 2003 workshop in Aspen and review of the workshop results with the Gemini Science Committee and Board, Gemini published four Calls for Proposals for new instrument studies on December 19, 2003. Two of these were calls for formal design studies, amounting to fixed-price bids to build the instrument from the study teams. The instruments to be covered by these studies were a high-resolution near-infrared spectrograph (HRNIRS) and an extreme adaptive optics coronagraph (ExAO-C). The remaining two calls were for less formal feasibility studies to resolve questions about technical feasibility and cost. The instruments covered by these studies were a prime focus fiber-fed extremely wide-field optical spectrograph (GWFMOS) and a ground-layer adaptive optics system (GLAO). NOAO took part in collaborations responding to each of the four calls, and all the proposals in which NOAO took part were successful. In the end, Gemini commissioned two competing teams for each of the two design studies (HRNIRS and ExAO-C), so as to ensure there would be competing bids to build these instruments. Gemini commissioned one team for each of the feasibility studies.
On HRNIRS, the NOAO Major Instrumentation Program joined forces with the University of Florida (UF) under the organizational leadership of the NOAO Gemini Science Center (NGSC). NOAO and UF each devoted substantial scientific, engineering, and managerial resources to preparing a science case, a conceptual design, and a detailed, bottom-up costing to support the joint bid to build this instrument. The final study was submitted to Gemini on February 28, 2005, and the design team defended the study in a formal review at Gemini Headquarters in Hilo on March 15, 2005. Gemini subsequently informed the team that their design had been selected as the winning design by the review panel. Following that, however, the Gemini Science Committee and Board concluded that Gemini’s budget for all the Aspen instruments was not sufficient to support building HRNIRS as proposed, so no contract was awarded in response to this study.

On ExAO-C, NOAO contributed scientific and managerial support to a design study partnership led by the University of Arizona. NOAO’s responsibility was for the science camera and its associated subsystems. That study was submitted to Gemini on February 25, 2005 and defended by the team at a review in Hilo on March 10. Gemini subsequently advised the team that their proposal was not chosen by the review panel, and a construction contract was awarded to the competing team.

On GWFMOS, NOAO participated in a large coalition (seven institutions) led by the Anglo-Australian Observatory by contributing both scientific and engineering staff effort. A. Dey of NOAO acted as Project Scientist for the coalition. The MIP contributed engineering and management support in the areas of wide-field corrector optics, telescope top end modifications, and detectors and controllers. This feasibility study was submitted to Gemini at the end of February 2005 and defended in a review presentation at Hilo in mid-March. Following this feasibility study, Gemini in September 2005 released an Announcement of Opportunity for two competitive design studies, again to result in two competing, fixed-price bids to build the instrument. NOAO will continue to support the coalition led by the Anglo-Australian Observatory.

Finally, on GLAO, NOAO is part of a team led by the University of Arizona. NOAO participated by providing data and analysis relating to turbulence profiles over Cerro Pachón,
through the scientific participation of A. Tokovinin (CTIO). This feasibility study was also delivered to Gemini at the end of February 2005, and defended at a review in Hilo in mid-March. Gemini released in September 2005 an Announcement of Opportunity for two competitive proposals to study the turbulence profile over Mauna Kea, Hawaii. Because NOAO does not have either the required equipment or the available personnel, NOAO did not respond to this Announcement.

3.2 NOAO INSTRUMENTS

NOAO Extremely Wide-Field IR Imager (NEWFIRM)

NEWFIRM, a world-class capability for wide-field imaging in the near infrared, is a key element in the U.S. system of facilities provided by NOAO. It has a $27 \times 27$ arcmin field of view with 0.4 arcsec per pixel at 1–2.4 microns and will operate at the R-C focus on either 4-m telescope (Mayall or Blanco). The instrument per se will be complemented by a highly automated data reduction pipeline feeding the NOAO data archive. Most of FY 2005 was devoted to completing the major mechanical fabrication and to beginning the initial assembly. Both the Tucson and La Serena shops devoted considerable resources to the fabrication effort. Careful attention was given to the coordination of mechanical engineering and drafting work between the two sites, and the joint fabrication process worked very well as a result. Initial mechanical assembly of the instrument began in June 2005, and the first test cool-down with the full mechanical assembly, but without optics or detectors, took place during August 2005. This test was largely successful, in that the instrument reached and held its operating temperature as planned. A number of problems were analyzed and solutions identified that will improve the dewar evacuation and enhance the mechanical and thermal stability of the instrument. A few weeks of mechanical re-work to implement those solutions was underway at the end of FY05.

Production of the aspheric optics—Lenses 1, 4, and 8—by the University of Arizona Optical Sciences Center (OSC) continues to be the pacing item for completion of NEWFIRM. OSC discovered early in FY05 that its finishing process could not deal with the curvatures required on Lenses 4 and 8. Arrangements were made to have Lens 4 finished by a subcontractor with a different process, and Lens 4 was delivered and accepted in June 2005. Lens 8 has an even more severe curvature and aspheric departure, and at the end of FY05, OSC and MIP are jointly looking for a subcontractor with the ability to finish the lens. Until a subcontractor is identified, no projection can be made with respect to delivery date. Lens 1 is within the capabilities of the OSC shop, but a number of unanticipated setbacks and problems prevented delivery in FY 2005. OSC now projects delivery of this lens sometime in the second quarter of FY 2006.
Raytheon Vision Systems (RVS) made some progress on the production of ORION II 2K × 2K InSb detector arrays for NEWFIRM in FY05. They completed four of the twelve devices called for under the foundry run contract. One of these four proved to be science grade despite a minor problem with the anti-reflection coating applied. RVS encountered some problems late in FY 2005 with the repeatability of certain process steps, and further work was halted while these problems were resolved and the contract renegotiated to deal with the extra costs imposed. Production is expected to resume early in FY 2006.

Electronics and software developments continue to proceed well and are not pacing the schedule. Also, the NOAO Data Products Program and the University of Maryland continued working jointly on the data handling system and data reduction pipeline to enable rapid scientific use of the large volume of data expected from NEWFIRM. This joint effort has completed the initial design and specification of both the data handling system and the pipeline, and work is underway now on producing the code modules that will be needed for delivery to the telescope. Some work on the data pipeline will necessarily have to wait until commissioning, for complete identification and removal of the instrumental signature and complete identification of all data products needed for both real-time observing support and later archival research.

Due primarily to continuing delays and uncertainties in the delivery of the aspheric optics, the initial delivery to the Mayall telescope is not expected to occur sooner than the last quarter of FY 06.
SOAR Adaptive Optics Module (SAM)

The SOAR 4.2-m telescope on Cerro Pachón will produce very high quality images over a field of view 10 arcminutes square. The SOAR Adaptive Optics Module (SAM) is designed to enhance this image quality by correcting the turbulence in the first 5–10 km of atmosphere, reducing the image size by half during appropriate atmospheric conditions, which are expected to be available about half the time. Following the FY 2004 “delta” Conceptual Design Review (delta-CoDR), the team developed the design and management plan. A formal Design Review is scheduled for early December 2005. The design is significantly more mature than is normal for a Preliminary Design Review, and the team will be seeking permission in this review to order optics and begin fabrication.

MONSOON Detector Controller

The Monsoon image acquisition system is the NOAO solution for scalable, multi-channel high-speed image acquisition systems required for next-generation projects. Monsoon is designed to be flexible enough to support CCD, CMOS and IR diode imaging arrays in a wide variety of uses, including science instruments, acquisition and guide cameras, and wavefront sensors. It is under development jointly by staff at both NOAO North in Tucson and NOAO South in La Serena. FY 2005 saw continued advancement for the project. The second “production” IR controller was delivered to the NEWFIRM project and awaits integration into the instrument. Revisions were completed to the last prototype design element, that of the CCD data acquisition board, and the first “production” versions of that board were received late in FY 2005. Delivery of the first “production” CCD controllers to KPNO and various WIYN and Blanco partners is expected early in FY 2006. Future developments throughout FY 2006 will focus on repacking the CCD controller design to reduce the space requirements and power consumption, matching the needs of extremely large focal planes such as the Dark Energy Camera (for the CTIO Blanco telescope) and the One-Degree Imager (for WIYN).
4.1 AURA NEW INITIATIVES OFFICE (NIO)

Based in Tucson, the AURA New Initiatives Office (NIO) is charged with “ensuring broad astronomical community access to a 30-meter-class telescope that will be contemporaneous with ALMA and JWST, by playing a key role in scientific and technical studies leading to the creation of the Giant Segmented Mirror Telescope (GSMT).” As a collaboration between Gemini and NOAO, the NIO has drawn on the expertise of NOAO and Gemini staff in Tucson, Hilo, and La Serena.

In FY 2005, NIO efforts focused on (1) support of the activities of the Giant Segmented Mirror Telescope Science Working Group, a broadly-based group charged with providing advice regarding investments in a GSMT which will achieve the goal of community access to a 30-m class telescope by the middle of the next decade, and (2) active participation in the technical and scientific working groups critical to advancing the TMT concept and initiating its Design and Development Phase. The following highlights additional FY05 accomplishments in specific areas.

Staffing

The NIO team is staffed primarily by NOAO engineers and scientists, many of whom have extensive experience with Gemini, WIYN, and SOAR. Key members of the initial NIO staff relocated in FY05 to join the TMT project in Pasadena. They have been replaced via internal and external recruitment. At present, 26 FTEs support NIO efforts.

Web Site

The NIO public Web site at http://www.aura-nio.noao.edu is an essential vehicle for communicating ongoing NIO activities, including the many technical studies completed by NIO staff, collaborating institutions, and subcontractors. The Web site, which is updated periodically, also contains copies of project presentations and links to the sites of other Extremely Large Telescope (ELT) groups.

GSMT Science Working Group (SWG)

The NIO created a community-wide GSMT Science Working Group (SWG) in response to a request from the National Science Foundation. The charge to the SWG is to “advise the NSF Division of Astronomical Sciences on a strategy for guiding federal investment in a Giant Segmented Mirror Telescope (GSMT).” Rolf-Peter Kudritzki, Director of the Institute for Astronomy at the University of Hawaii, is the chair of the GSMT SWG, with NOAO’s Steve Strom as vice-chair. In FY04, the SWG presented the conclusions of its first major report, “Frontier Science Enabled by the Giant Segmented Mirror Telescope,” to the Astronomical Sciences Division of the NSF and to the Committee on Astronomy and Astrophysics (CAA). This report, which is available at http://www.aura-nio.noao.edu/gsmt_swg/SWG_Report/SWG_Report_7.2.03.pdf, recommends vigorous NSF investment in the GSMT technology development program.

In September, 2005, in response to a request from the Astronomy and Astrophysics Advisory Committee (AAAC), the SWG issued “A Giant-Segmented Mirror Telescope: Synergy with the James Webb Space Telescope” (http://www.aura-astronomy.org/nv/GSMT_SynergyCase.pdf), a report designed to advance qualitative and quantitative understanding of the complementarity between JWST and a 20–30-m Extremely Large Telescope (ELT). Throughout FY05, the SWG continued to provide a public forum for discussion of technical progress and scientific capabilities of the two ongoing U.S. ELT programs: Giant Magellan Telescope (GMT) and Thirty Meter Telescope.
The SWG also met jointly with European Southern Observatory (ESO) scientists to advance mutual understanding of the scientific capabilities of telescopes ranging in aperture from 20–30 m, to 50–60 m and 80–100 m, and is preparing a white paper, which will be released in mid-FY06, outlining scientific performance of ELTs as a function of aperture. The SWG has also enjoyed high-level representation from the Japanese astronomical community. Several investigations of the GSMT SWG were supported by NIO staff members, who carried out technical, performance simulation, and project planning studies.

**Thirty-Meter Telescope (TMT) Partnership**

In May, 2003, Letters of Intent to participate in a joint Design and Development of a 30-m class ELT were signed by AURA, the California Institute of Technology, the University of California, and the Association of Canadian Universities for Research in Astronomy (ACURA). The four partners have agreed to refer to the joint effort as the Thirty-Meter Telescope (TMT) project.

The Letters of Intent state that each party will solicit funding from appropriate agencies to support the Design and Development phase of the TMT project. The California Institute of Technology and the University of California—which together have formed the California Extremely Large Telescope (CELT) Development Corporation—have received funding in the amount of $35M from the Moore Foundation, while ACURA has been awarded funds from the Canadian Foundation for Innovation (CFI). AURA-NIO submitted a proposal to the National Science Foundation that would provide funding in the amount of $17.5M as its share of the Design and Development Phase for TMT. Participation by AURA in TMT provides a strong voice for the U.S. community in shaping the design of the telescope and ensuring that its capabilities meet community aspirations. The TMT partners have agreed that all federal investment in TMT will result in access for the U.S. community.

The TMT partners have established an Interim Board of Directors, on which NOAO director J. Mould serves, and a Science Advisory Committee (SAC), on which S. Strom, J. Najita, and J. Jensen (Gemini) are the AURA representatives, while K. Glazebrook (Johns Hopkins U.) serves as a community representative through AURA. The SAC is charged with developing and updating a Science Requirements Document and interacting with the TMT project office as cost-risk-performance trades are identified during the Design and Development Phase.

**AURA Proposal to NSF**

The July, 2004 proposal submitted by AURA to NSF requested $39.4M to provide:

1. The public portion ($17.5M) of the funds needed to carry out the Design and Development Phase for a 30-m diameter segmented-mirror, optical/infrared telescope (i.e., TMT)
2. Funds ($14M) sufficient to advance to the Design and Development Phase an alternative 20–30-m-class concept, such as the Giant Magellan Telescope (GMT), to the point where its performance, cost, and risk can be assessed
3. Technology development ($2M) common to both TMT and the alternative concept
4. $1.5M for community groups to carry out conceptual designs for two instruments: one for TMT and one for the alternative concept
5. $3.5M to support an education and public outreach program
6. $0.9M to support a Theory Challenge program aimed at engaging theorists in shaping the design of ELTs.
The first of these investments will leverage the $35M in non-federal funding (donated by the Moore Foundation to the California Institute of Technology and the U. of California), plus funds requested of the Canadian Foundation for Innovation (CFI), and will enable AURA to participate fully on behalf of the U.S. community in a partnership to advance TMT to a fully-costed Preliminary Design by the end of 2007.

The second major investment will support a design study aimed at developing an alternate technical approach. One such example is the Giant Magellan Telescope (GMT): a concept that provides the collecting area of a 21.5-m telescope by combining the light from seven 8.4-m mirrors. The GMT project, a partnership among the Carnegie Institution, Harvard/Smithsonian, the U. of Arizona, the U. of Michigan, and the Massachusetts Institute of Technology, is currently in the midst of its Conceptual Design Phase.

AURA will ensure strong community participation by both observers and theorists in shaping each of the ELT designs, so that the resulting facility performance fully meets community aspirations. This approach will allow AURA to keep apprised of the progress of both ELT programs in order to maximize transparency of technical studies, and to ensure that the imagination and technical talent in the U.S. community is fully engaged in developing key technologies and instrument concepts.

This joint approach has a precedent: NSF support of mirror technology in the 1980s, technology development that eventually led to the successful development of the Keck, Magellan, MMT, LBT, and Gemini telescopes. In this case, however, all of the NSF funding will result directly in community access to these telescopes. Moreover, the adaptive optics and detector technology will benefit the current generation of 6–10-m telescopes.

Initial funding in the amount of $1M was received at the end of FY05. These funds will be split between TMT and GMT per the proposal submitted by AURA in July 2004 on behalf of the U.S. community.

Site Testing for the Thirty-Meter Telescope

Starting with a Memorandum of Understanding (MOU) with the California Extremely Large Telescope (CELT) group in FY 2002, AURA has played a major collaborative role in evaluating candidate sites for TMT. The work is now ongoing as a major work package for the TMT Project. The list of candidate sites has been narrowed by investigations of logistical issues such as land ownership, as well as by a series of remote sensing studies that have used satellite data to quantify the number of clear nights and the precipitable water vapor for each site. Each prime candidate site has also been modeled using computational fluid dynamics to investigate the boundary layer turbulence over the site under various wind speeds and directions.

In-situ site testing equipment has been developed, and multiple copies have been purchased and assembled. This equipment includes weather stations, differential image motion monitors (DIMMs) capable of recording integrated seeing through the upper atmosphere and ground-layer, and multi-aperture scintillation sensors (MASS) capable of mapping turbulence profiles above candidate sites. Weather stations, DIMM and MASS units have been deployed on several candidate sites; deployment will be complete in early 2006.

Towards the end of FY04, TMT site testing activity was re-organized under direct project control. At that time, the Sites Working Group (SWG), jointly chaired by Caltech and NOAO, evolved into an advisory group; the group now functions as an efficient interface with other U.S. and international groups (e.g., Giant Magellan Telescope, Cornell, ESO) that are actively testing for new facilities or considering doing so in the future. In June 2005, the SWG organized a technical workshop in Vancouver that focused on measurement of vertical turbulence profiles in the atmosphere. The workshop was well-attended by all those active in this field—which is critically
important for adaptive optics system design. An MOU was signed with ESO specifically covering analysis of similar data sets of turbulence profiles from different observing sites.

A full set of site testing equipment was installed at the second candidate Chilean site in FY05, and operation at the first Chilean site continued. The equipment consists of a weather station, a Differential Image Motion Monitor (DIMM), and a Multi-Aperture Scintillation Sensor (MASS) powered by an array of solar panels. The DIMM and the MASS are fed by a 14-inch aperture telescope atop a 6-meter tower. Other equipment, such as Sound Detection and Ranging Systems (SODAR) are operated robotically as well, but the equipment is moved from site to site on multi-month timescales since there are fewer units than sites. The first two sets of SODAR for Chile were operated side by side on Chilean site 2 to cross calibrate and verify their operation. One set is expected to move to site 1 and another to site 3 in FY06. During FY05 the permitting process was completed to allow access to the first high (4500m) site (Chilean site 3) to be tested in Chile for the TMT. Besides the official permits from numerous Chilean government agencies, the process involved several face-to-face meetings with local communities to explain the TMT site testing goals and process. The construction of an access road is underway, and early in FY06, installation of site testing equipment on the summit is planned. Initial documentation was submitted to begin the process for acquiring access to a second Chilean high site (4200m, Chilean site 4).

The NOAO site testing group also participated in the installation of sets of TMT test equipment on Mauna Kea, Hawaii and at San Pedro Martir, Mexico. For each of the TMT sites, all-sky cameras designed and built at CTIO are being installed; these cameras were also installed at Las Campanas and San Pedro Martir in support of the GMT and LSST projects, and have been in routine operation on Cerro Tololo and Cerro Pachón for some time. The CTIO shops are also fabricating the mount for a Canadian precipitable water vapor monitor called IRMA, which will be used at all TMT sites.

A new postdoctoral research associate, Sebastian Els, joined the CTIO-TMT sites group in late FY05. Els is charged with leading the data analysis of the TMT site survey. He will also work closely with the rest of the CTIO group in all aspects of TMT site testing.

**TMT Interim Tasks**

NIO staff are making major contributions to technical development activities key to the successful completion of the Design and Development Phase for TMT. Specific work packages include:

- Design of a Mid-Infrared Echelle Spectrograph (MIRES) in collaboration with U. Hawaii
- Developing an Observatory Requirements Document and Traceability Matrices for eight science instruments
- Developing a Design Concept for a Laser Launch Telescope
- Developing the support systems for the secondary and tertiary mirrors

**FY 05 Technical Papers by NIO Staff and Affiliated Gemini and NOAO Staff**

- Submitted to SPIE Conference, Optics and Photonics, at the SPIE 50th Annual Meeting: Celebrating 50 Years of Excellence, San Diego, CA, July 31-August 4, 2005
- Myung K. Cho, Mark Warner, and Joon Pyo Lee, “Structural Analysis for the 4-m Advanced Technology Solar Telescope (ATST)”
4.2 **LARGE-APERTURE SYNOPTIC SURVEY TELESCOPE (LSST)**

The Large-aperture Synoptic Survey Telescope (LSST) is one of three major new ground-based facilities recommended for construction during the coming decade by the AASC. It has also been recommended as a high priority by two additional NRC decade surveys, one dealing with the interface between physics and astrophysics and the other with solar system exploration. A report by the Office of Science Technology Policy (OSTP) highlighted LSST as one of three high priority facilities for characterizing dark energy.

The LSST Corporation, of which NOAO is a founding member, now has eight member institutions, and two more applications are pending. The chief officers of the project continued in their positions: John Schaefer from Research Corporation is President, the Director is Tony Tyson of UC Davis, and Don Sweeney from LLNL is project manager. Bill Althouse (Stanford/SLAC) is serving as systems engineer, and Zjelko Ivezic (U. Washington) was recently appointed as the systems scientist. ([See: http://www.lsst.org/lsst_home.shtml](http://www.lsst.org/lsst_home.shtml))

The project scientists and project managers for the three major components of the project are also now in place. Respectively, they are Steve Kahn and Kirk Gilmore (Stanford/SLAC), for the DOE effort to design the camera; Chuck Claver and Victor Krabbendam (NOAO) for the telescope and associated facilities (Krabbendam is also the deputy project manager for the entire LSST project); and Tim Axelrod (Steward Obs.) and Jeff Kantor (LSSTC) for data management. Near the end of FY05, the proposal for the design and development phase of the project was funded by the NSF. The goal of the project is to complete a construction proposal at the beginning of FY07.

The science requirements for the LSST are now documented and under change control. The optical design provides a 3.5 degree FOV, and the fabrication plan currently being analyzed by the U of A involves casting the primary and tertiary mirrors together as a single monolith. Private funding has been used to contract with the University of Arizona to begin acquisition of materials for the primary and tertiary and to complete detailed analysis of the monolithic design. Private funding is key to early acquisition of items requiring a long lead time and hence to timely completion of the project.

Three sites remain under consideration: San Pedro Martír, Cerro Pachón, and Las Campanas. We are continuing to collect data at all three sites, and we will shortly issue RFPs to the three sites asking for information that would allow us to evaluate each in terms of costs and risks for both construction and operation. The goal is to select the site at the LSSTC Board meeting in April, 2006.

A team based at NOAO is responsible for telescope construction and site development. NOAO staff have developed an observing simulator that can be used to model various observing strategies along with the observing conditions at each of the possible sites in order to determine the feasibility and compatibility of the various science goals. The work on the simulator is being shared with PanSTARRS and further work will be carried out jointly. NOAO scientists have played a major role in formalizing the science requirements for the telescope and are providing input to the requirements for the data and archiving systems.
4.3 National Virtual Observatory (NVO)

Creation of a National Virtual Observatory (NVO) was the highest ranked priority initiative of the National Academy of Sciences decadal survey in the “small project” (less than $100 million) category. NOAO has been involved with the development of the NVO from its inception and has continued to play a significant role as this project has moved from the conceptual to the development stages.

In FY 2005, the contributions from NOAO to the NVO continued at both the management and programmatic levels. D. De Young continued as a member of the NVO Executive Committee and as the Project Scientist of the NSF/ITR NVO initiative. De Young is also a member of the Executive Committee of the International Virtual Observatory Alliance (IVOA) and a member of the IVOA Theory Working Group. A significant milestone was reached in 2005 with the release of the first suite of NVO science application tools. These tools were unveiled at the January 2005 AAS meeting in San Diego, and are designed to provide useful utilities that are simple to use and that will significantly enhance the research capability of the U.S. astronomical community. The applications released include a registry portal, a multiwavelength image retrieval service, a general cross match service, a Web enabled image analysis service, and a spectrum retrieval service. In addition, a self-contained package on data publication was also created. This release was accompanied by demonstrations given at the AAS meeting, and in addition, each application is accompanied by a “self-help” tutorial package. The philosophy behind the creation of these tools reflects a basic tenet of the U.S. NVO, and that is to create tools and libraries that will engage the astronomy community as a whole. This philosophy differs somewhat from that taken by the European VO efforts, where more emphasis has been placed on end-to-end scientific demonstrations carried out by individuals directly associated with the VO projects.

In addition to this important release to the community, the NVO is continuing to develop additional applications or to refine existing ones. To facilitate this effort, the NVO Science Steering Committee (SSC), chaired by De Young, at its July 2005 meeting in Pittsburgh, examined the current suite of science applications. After discussion with the NVO team, the SSC then provided a prioritized list of further developments that the project should undertake in the final year of the infrastructure development program. Some of these suggestions involved the further development of existing science applications, while others described new applications to be developed.

A further science-motivated activity initiated in FY05 by the NVO was the planning and development of an NVO Research Initiatives program that will provide small ($25K) research grants on a peer-reviewed basis to members of the astronomy community who wish to carry out NVO-based research or to develop NVO-related software programs. The call for proposals for this program was announced in August 2005, and the final awards will be announced in early FY 2006.

De Young and M. Fitzpatrick also attended the International Virtual Observatory Alliance (IVOA) inter-operability meeting in Kyoto in the spring of 2005, where significant progress was made in further refinement of technical aspects of international VO projects and where specific goals were set for the development of theory in the these projects. In addition, De Young attended the IVOA Executive Committee meeting in Kyoto as well as the NVO Team Meeting and SSC meeting CMU in July 2005. Also attending this latter meeting from NOAO were M. Fitzpatrick, C. Miller, R. Seaman, R. Shaw, and F. Valdes. Finally, a second successful NVO Summer School was held in September 2005 in Aspen, Colorado. Faculty at the summer school from NOAO included D. De Young, M. Fitzpatrick, and C. Miller. Attending as students from NOAO were R. Seaman and F. Valdes.

In addition to these activities, NOAO is continuing to ensure that large-scale new projects in which it is engaged, such as PanStarrs and LSST, will be compliant with NVO standards and compatible with NVO protocols when these projects become mature. The NOAO is also well along
in developing its data archive and pipeline systems for ground-based optical/IR data that will provide an accessible interface with, and portal to, the NVO. A more complete description of these efforts is given in the Data Products Program section of this Annual Report.

4.4 Telescope System Instrumentation Program (TSIP)

The Telescope System Instrumentation Program (TSIP) had its fourth annual cycle in FY 2005. TSIP has the goal of strengthening the system of public and private optical/IR facilities by funding the development of facility instruments for large private telescopes and thereby broadening community access to these telescopes. The program was established in FY 2002 as a $4M per year program administered and coordinated by NOAO for NSF. In May 2004, NOAO held a community workshop to discuss the status and plans for the ground-based O/IR system of facilities. One of the goals of this workshop was to review the status of TSIP and to update the guidelines and instrument priorities. The recommendations, which include efforts to broaden the program by allowing proposals to improve instruments or operations, and to encourage proposals from smaller telescopes, were incorporated into the FY 2005 solicitation. The complete report of the workshop is available at [http://www.noao.edu/meetings/system2/system2_report.pdf](http://www.noao.edu/meetings/system2/system2_report.pdf).

The solicitation for the FY 2005 cycle was issued in October 2004, and five Letters of Intent to propose were received in December 2004. Four proposals were received by the deadline at the end of February 2005. Only $2M of new funding was provided this year for TSIP, to supplement approximately $1.4M that was carried over from previous years. The four proposals requested a total of almost $18M. A peer review panel, chaired by S. Hawley (U. Washington), included individuals with appropriate instrumental and scientific expertise. This panel reviewed the four proposals in April 2004 and recommended funding two of them, one for ODI (One Degree Imager) a wide-field optical imager for the WIYN 3.5-m telescope, and one for the first year of work on MOSFIRE, a multi-object near-infrared spectrograph for the Keck-1 telescope. T. Boroson and S. Hawley presented the panel recommendations to NSF/AST in May 2004.

The WIYN sub-award will provide 40 additional community nights with ODI starting in 2009. In addition, community participation will be solicited in a 70-night survey project that is being organized by Yale University. The Keck sub-award will provide 24 nights on the Keck telescopes in the 2006A and 2006B semesters.

Throughout FY05, T. Boroson and M. Trueblood participated in management oversight activities for the instrumentation projects funded in previous TSIP cycles. These activities included monthly reports (both written and via teleconference) from the projects OSIRIS, MMIRS, and MODS. In addition, Boroson and Trueblood attended reviews of MMIRS and MODS. OSIRIS was completed, delivered, and is currently being commissioned on the Keck-II telescope.

4.5 Adaptive Optics Development Program (AODP)

Following the successful model of the Telescope System Instrumentation Program, the Adaptive Optics Development Program (AODP) was established in 2003 to advance technologies critical to the development of AO systems on future- and current-generation large telescopes. NOAO was asked by the NSF to take responsibility for (a) developing and updating an AO “road map” aimed at identifying areas critical for investment, (b) setting up a Web site for the program and issuing the first program description/proposal solicitation ([http://www.noao.edu/system/aodp/](http://www.noao.edu/system/aodp/); (c) assembling the external peer-review panel and process for evaluating received proposals, and (d) monitoring progress against plan of awarded projects.
Six awards for development programs spanning three to five years duration were made following a community-wide solicitation of proposals. A reduction in funding has limited investment to supporting the six proposals selected in 2003.

The awarded programs include two efforts to develop low-noise detectors for wavefront sensors, two to develop reliable sodium lasers, one to develop advanced deformable mirrors, and one to develop new wavefront sensing algorithms. The funded groups are all making satisfactory progress. NOAO staff involved in tracking the funded projects include S. Ridgway, S. Strom, and Technical Manager, D. Eklund.
5.1 **Educational Outreach (EO)**

NOAO’s Educational Outreach group is responsible for managing and developing the national observatory’s efforts in formal and informal science education. NOAO EO programs train teachers and astronomers to communicate scientific research principles and the latest discoveries in astronomy to pre-college students. The EO group also supports the Research Experiences for Undergraduate programs at Kitt Peak and Sacramento Peak, and helps facilitate graduate and post-graduate opportunities at KPNO and CTIO.

FY 2005 highlights in educational outreach included observations with the Spitzer Space Telescope by six teams of TLRBSE teachers and staff astronomers from NOAO and the Spitzer Science Center, and major progress in field-testing the first three kits of optics engineering activities under a $1.7 mil. NSF informal science grant for “Hands-On Optics.”

**Teacher Leaders in Research-Based Science Education**

In FY05, the NOAO Teacher Leaders in Research Based Science Education (TLRBSE) program completed the second year of its three-year transition to full core funding in the NOAO budget, as mandated by the NSF Education and Human Resources (EHR)-funded grant that established the program. TLRBSE held its most successful summer workshop ever, and gave 12 veterans of the program the unprecedented opportunity to observe with the Spitzer Space Telescope. K. Garmany took over day-to-day leadership of TLRBSE, with S. Pompea continuing as project director. A second all-electronic recruiting campaign drew 140 qualified applicants for the 2005 program, with the selected teachers hailing from across the country, from Hawaii to Maine and from Minnesota to Florida.

Eighteen teachers in the 2005 cadre completed an intensive 15-week distance-learning course and then met in Tucson over two weeks ending July 4 for advanced training on astronomy research projects as well as mentoring and leadership training. This year’s cadre of teachers was outstanding in every respect and made maximum use of the distance learning course and immersion workshop in Tucson. An extra-exciting event graced the portion of the TLRBSE workshop conducted on Kitt Peak: on June 30: the TLRBE teachers made some of the first scientifically useful observations of a new supernova in M51. Details are provided in a press release at [www.noao.edu/outreach/press/pr05/pr0507.html](http://www.noao.edu/outreach/press/pr05/pr0507.html).

Four TLRBSE-related workshops were held at the National Science Teachers Association meeting in Dallas in late March, 2005. Successful alumni of the program made presentations at each of our workshops, which were uniformly well-received.

Five of the six TLRBSE Spitzer teachers obtained data from the spacecraft during the year, and five teacher-student groups visited Pasadena to work with staff astronomers on reducing their data. Early results are promising enough to encourage the SSC director to propose a second round of the program, and early science results will be reported at the January 2006 AAS meeting.

Previous TLRBSE project manager S. Croft is now developing a new middle school TLRBSE project related to asteroids that can also be used as part of the LSST education and outreach effort, with partial support from LSST Design and Development phase funding that arrived late in the year.

This was the second year of this advanced TLRBSE Teacher Observing Program (known as TOP): the proposals received were of much higher quality than last year, reflecting a better understanding by the teachers of what was expected. Teachers first submitted a short summary of what they hoped to do: the best were chosen and a longer submission was requested from the student group, along with phone interviews. Teams were selected for a total of three runs on the 0.9-m
telescope (K. Garmany), two runs on the solar telescope (C. Walker), and two runs on the coudé feed (S. Howell). All reports from the teacher-student groups were very positive, even when a run was almost completely lost to snow and fog. A total of seven teachers and 14 high school students participated in the TOP program during the spring of 2005.

Project ASTRO/Family ASTRO

To better accommodate the needs of teachers to satisfy science standards set by school districts, Project ASTRO-Tucson held its first experimental workshop for the Catalina Foothills School District on Thursday-Friday, June 9-10, 2005. A group of seven 5th and 7th grade teachers (grades within which astronomy is being taught) and ten astronomer partners attended the two-day workshop at Esperero Canyon Middle School. Highlights of the workshop included a scale-model solar system activity using the school’s playing field, a talk on different group learning styles and techniques by Janelle Bailey of the UA Conceptual Astronomy and Physics Education Research Team, a “kinesthetic astronomy” activity led by Robert Wilson of NOAO, updates on NASA space programs by NASA solar system ambassador, Loretta McKibben, and an inspirational talk on comets past and present by renown comet hunter and author David Levy.

The Project ASTRO 2005 follow-up workshop held on February 12, 2005, included a talk on “Lifting Titan’s Veil – New results from Huygens” by Ralph Lorenz of the University of Arizona Lunar and Planetary Lab research staff. The 30 participants built Sun clocks, demonstrated a reflective solar cooker, plotted apparent daily motions of the Sun, discussed sunspots relative to solar rotation, and tried to observe the location of the setting Sun and the phase of the Moon as part of the evening’s training activities. For the third time in as many years, David and Wendee Levy hosted the workshop with NOAO at their home-based observatory in Vail, Ariz.

A total of 33 new teacher-astronomer Project ASTRO partnerships were formed in FY05, directly impacting an estimated 5,700 students in Tucson and surrounding communities. An estimated 160 Project ASTRO partnerships are currently active.

Fifteen Family ASTRO events were conducted throughout the year at sites including the U.S. Park Service at Sabino Canyon, the Discovery Park in Safford, the Arizona Virtual Academy, the Flandrau Planetarium, Pima County Natural Resources, Parks and Recreation, numerous elementary schools in Tucson Unified School District and the Catalina Foothills District, Catalina Community Center, and Drexel Heights Community Center. These programs reached about 350 families in southern Arizona.

Two PAEO staff members attended and made presentations at the annual ASTRO Site Leaders meeting.

ASTRO-Chile

The NOAO ASTRO-Chile effort continues to expand its bilingual outreach program in astronomy education with great enthusiasm at NOAO North and South. Spanish-speaking science teachers from Tucson middle schools and high schools attend regular video conferences with Chilean teachers from various grades from the region surrounding La Serena, assisted by NOAO scientists and outreach personnel from both North and South.

More than a dozen students and teachers on each side of the equator participated in the seventh major NOAO ASTRO-Chile videoconference between Tucson and La Serena, held on April 16, 2005, in honor of Astronomy Day. Middle school- and high school-age students at both sites gave presentations on the results of light pollution observations made by hundreds of
participants in the two locations over the previous several weeks. Two of the three Tucson presentations were conducted in Spanish. The findings were presented via PowerPoint slides, maps, posters, and written reports.

Tucson Unified School District participants in the videoconference hailed from Tucson High School, Gridley Middle School and Vail Middle School. The La Serena attendees included many of the students and teachers that have participated in the most recent training workshops conducted by the local RedLaSer educational outreach group, which is funded in part by Gemini South and Cerro Tololo Inter-American Observatory, with support from the University of La Serena.

Other Educational Outreach Programs

**Hands-On Optics**
The NSF-funded ISE “Hands-On Optics” is creating six optics teaching kits and training science center educators and after-school program leaders nationwide. Development and testing work continues on Modules/Kits 4-6 which cover color, polarization, ultraviolet fluorescence, near infrared light, and optical communication. Late summer workshops were held at U. Southern California and at Lawrence Livermore National Laboratory, and major planning was done for the formal Arizona debut of the program in a special education session at the annual meeting of the Optical Society of America in Tucson in October 2005. Other HOO workshops were conducted or scheduled in Colorado, New Mexico, Utah, Washington state, and Maryland.

HOO kits are being used and tested by NOAO-trained staff at New York Hall of Science in Queens, the Orlando Science Center, the Museum of Science, Boston, Houston Museum of Natural Science, the Lode Star Astronomy Center of the New Mexico Museum of Natural History and Science, and the Adventure Science Center in Nashville. An April 2005 HOO-sponsored MESA optics competition in Arizona, now in its second year, had 12 high school teams and 15 middle school teams competing and building a Newtonian reflecting telescope. HOO supplied optics parts for the competition, the judges, as well as the competition write-ups.

**Astronomy from the Ground Up**
The “Astronomy from the Ground Up” NSF ISE project with the Astronomical Society of the Pacific (ASP) and the Association of Science Technology Centers had a retreat in May 2005 as a kick-off meeting of the project principals. The project will provide professional development in astronomy for science centers nationwide and will also develop teaching kits in astronomy that are suitable for an informal science institution. A variety of recruiting efforts and supporting materials and graphics were produced by the team in preparation for the project’s first major workshop in April 2006 in Tucson.

**Investigating Astronomy**
The “Investigating Astronomy” NSF Instructional Materials Development (IMD) project with TERC and the ASP has ramped up in this quarter with Steven Croft playing a key role in the creation of a large number of images suitable for the new national high school, standards-based astronomy curriculum. Croft has played a key role in the project in the choice of astronomical imagery, image processing tools, and other software tools into this curriculum. Croft is preparing for a major project meeting in August.
**Collaborative to Advance Teaching, Technology, and Science (CATTS)**
The NSF-funded “Collaborative to Advance Teaching, Technology, and Science” (CATTS) GK–12 project continues at NOAO with graduate CATTS Fellows Erin Doktor and Janelle Bailey (both Ph.D. candidates in the Conceptual Astronomy and Physics Education Research (CAPER) Team at Steward Observatory) working in the classroom with teachers in the Tucson area.

K. Garmany taught her second class in Introductory Astronomy at Tohono O’odham Community College in Sells, Ariz. Four students completed the class, which met twice a week. They receive credit through Pima Community College if they decide to transfer. The class made two trips to Kitt Peak, participating in the Nightly Observing Program and getting a special telescope tour.

**EO Meetings and Events**
With the help of 18 volunteers, the NOAO educational outreach and public outreach groups co-hosted a booth with seven hands-on activities in astronomy, a portable planetarium, and solar observing at the 3rd Annual Math, Science, and Technology Funfest, March 16–18, 2005, at the Tucson Convention Center. Held in conjunction with the yearly Southern Arizona Regional Science and Engineering Fair (SARSEF), FunFest brought together scientists and elementary through high school students to share in the wonders and excitement of science. The event was held at the Tucson Convention Center and attracted over 5,800 students and 1,200 adults over three days.

For the second consecutive year, EO staff (S. Pompea, S. Croft, and C. Walker) represented NOAO at the December, 2004 AGU meeting, leading three sessions on teacher professional development programs promoting authentic research in the classroom. Eight talks were given in each of two oral sessions and seven posters in one poster session. The varied topics underscore the remarkable breadth of our EO scientists: astronomy; seismology; oceanography; geology; polar research; physics; digital science libraries; distance learning courses. The NOAO EO staff chaired three sessions as well, with each giving a presentation in the oral sessions on various aspects of the TLRBSE program.
In October, 2004, EO staff scientists Walker, Pompea, and Croft convened and chaired three sessions for teachers at the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) conference in Austin, Tex., including one titled Recent Developments of Spanish Language Educational Materials for Astronomy and Related Sciences. Representatives of various science education outreach programs presented Spanish language materials featured prominently in their programs. An intense discussion with the teachers followed the seven presentations. Teachers and presenters alike agreed to propose a sequel to the session at next year’s SACNAS meeting. The participants (about 30 K–12 teachers) also worked through two TLRBSE activities. Participants received hard copies of the activities as well as a CD containing the activities and other NOAO/PAEO materials, which were well-received.

Research Experiences for Undergraduates (http://www.noao.edu/kpno/reu/)

KPNO continued its long-standing participation in the NSF Research Experiences for Undergraduates (REU) program, preparing future generations of professionals who will sustain U.S. preeminence in astronomy and contribute to a scientifically-literate nation. NOAO scientist K. Mighell is the site director for the REU summer program in Tucson; A. Whiting headed the REU program at CTIO in FY05.

Over the FY05 summer, the six undergraduate students in the KPNO program worked closely with NOAO Tucson staff for a 10–12 week period, developing skills as scientific researchers and furthering their professional development. CTIO hosted six U.S. REU students and two Chilean undergraduates under the similar Prácticas de Investigación en Astronomía (PIA) program.

(Five more REU students worked with staff of the National Solar Observatory, with direct logistical support from PAEO staff.)

In September, K Mighell represented all of the NSF astronomy REU programs at a national meeting of the program, and his important efforts to recruit more under-represented minority students were highlighted in an article in the September 2005 Physics Today.
**Astronomy Education Review (AER)**

The *Astronomy Education Review* (AER), a refereed online journal at [http://aer.noao.edu/](http://aer.noao.edu/), is now in its fourth year of operation. The goal of the journal, which is edited by S. Wolff and A. Fraknoi (Foothills Community College), is to disseminate research about astronomy and space science education, along with innovative ideas for classroom use, resource lists, reviews, and commentary.

By every metric, the journal has been extremely successful. In FY05, it continued to receive a steady stream of papers from well known leaders in the field of astronomy and space science education and from instructors with innovative ideas who are working in a variety of institutional settings. The papers are being read, as indicated by the statistics for the Web site. During the school year, the journal has received as many as 200,000 hits in a month from 91 different countries, and we estimate that 100 papers are downloaded each day. The online articles cover a wide range of topics, from elementary to college-level education, including the teaching of students with disabilities, and therefore, as we hoped, the journal is serving a diverse audience. A new feature added this year is a section for opinions.

The most recent issue provided three articles with extensive lists of resources to assist teachers in dealing with questions about intelligent design. These articles are especially timely given the current trial in Delaware, and we have received many letters of appreciation from readers. Other articles have received favorable comments as well. The following is typical: “The article [by Kavanagh et al.] is a great review of the work on lunar phases—a must-read for people who are trying to understand people’s misconceptions and effective techniques for teaching.”

We have approached both the AAS and the ASP about taking over the journal and providing a secure, long-term home for it. Discussions are in progress.

### 5.2 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 program, and the popular fee-based nighttime observing experiences for both the general public and advanced amateurs.

**Kitt Peak Visitor Center**

In FY05, the staff of the Visitor Center continued to improve infrastructure and expand programming, including the initiation of a new formal Kitt Peak membership group for the public. Membership in this program ($35 individual, $55 family) entitles the member to special discounts, a newsletter, and a members-only star party, among other benefits.

The Visitor Center hosted two major combined media/public outreach events in FY05: one for the October 27, 2004 lunar eclipse, during which an image of the Moon from the...
Visitor Center 20-inch telescope was fed live to Tucson’s KOLD CBS-TV News, and one for the collision of the NASA Deep Impact probe with comet Tempel 1 on the night of July 3, 2005, which produced some unique, nearly-live still images and movies of the event for public access via the Web.

The Kitt Peak Visitor Center was packed with a larger-than-normal crowd of 55 people for a sold-out event the night of the collision between the NASA Deep Impact spacecraft and Comet Tempel 1. The public heard talks from observers at Kitt Peak studying the comet and from Kitt Peak Director Richard Green, then cheered along with mission team members.

Special night programs for the public were conducted for the Geminid and Perseid meteor showers, and “Einstein Day” was celebrated at the Visitor Center on Saturday, March 12, for more than 75 people in honor of Einstein’s birthday and the World Year of Physics 2005. Other special events included CCD imaging classes, “Fun With the Sun” family events, an evening of music under the stars with the Tucson Junior Strings Quartet, and several annual events with the Tucson Amateur Astronomy Association.

Visitor Center improvements in FY 2005 included new paint and tile floors, along with new color image prints to help revitalize the Mayall 4-m telescope visitor gallery. Nearly two dozen new docents successfully completed their training and began their volunteer work.

Other Public Outreach

NOAO staff arranged and conducted numerous special tours and talks for schools, university groups, and film and video production companies in FY 2005, including OSTP Director John Marburger, OMB science budget chief David Radzanowski, Carolyn Shoemaker, Discovery Channel, attendees from the annual AIAA joint propulsion conference, staff and volunteers from Organ Pipe Cactus National Monument, the University of Arizona Elderhostel, the new Laurel Clark Earth Camp (honoring the late NASA astronaut), and a week-long astronomy day camp conducted by public outreach staff and organized by Arizona Youth University–University of Arizona and attended by 13 middle school and high school students.
PAEO public outreach staff worked with the Tucson Airport Authority to secure a second run of 3-foot by 8-foot banner space in the luggage claim area of the airport, again at no charge. This colorful and attractive second-generation banner advertises Kitt Peak and its public programs to hundreds of arriving passengers per day.

Coordination with the External Community

NOAO was the anchor for a major week-long series of international astronomy outreach meetings in Tucson during mid-September 2005, all carried out with great success. On Monday, the public information officers from the seven Gemini Observatory partners met at NOAO after touring Kitt Peak on the previous afternoon. On Tuesday, 20 members of the international STARTEC group of observatories with public outreach functions also met at NOAO. Then from Wednesday-Friday, the Astronomical Society of the Pacific held its annual meeting for 2005 at the Doubletree Hotel—the meeting focused for the first time on the emerging profession of astronomy education and public outreach. More than 370 people attended the meeting, which received extremely positive reviews from numerous attendees and participants; it is likely that future ASP annual meetings will carry this outreach theme onward.

Public Outreach Manager R. Fedele represented NOAO at the 2nd “Communicating Astronomy to the Public” Conference, held at ESO in Munich, Germany in mid-June. Fedele was also an invited keynote speaker at two Arizona Office of Tourism regional workshops on astronomy tourism in Arizona attended by more than 100 tourist industry professionals.

PAEO staff also continued to contribute significantly to the Southwestern Consortium of Observatories for Public Education (SCOPE).

5.3 Media and Public Information

NOAO’s media and public information group coordinates news releases, media events and visits, fact sheets, posters, the NOAO Newsletter, and other visual products that explain NOAO’s latest research and organizational activities. It also coordinates NOAO’s public Web presence and external use of NOAO imagery, and serves as the primary response point for public inquiries and general e-mails.

Press Releases and Image Releases

NOAO issued nine formal press releases in FY05 and worked extremely closely with the Gemini Observatory, the Spitzer Science Center, and NASA on several others (see Table below). Other media highlights of the year included a major photo essay on Kitt Peak in the May 2005 issue of Discover magazine (including the cover headline “Kitt Peak: Telescope Heaven”), a steady stream of local news and feature stories in Tucson’s largest daily newspaper, The Arizona Daily Star, and an overnight visit and subsequent magazine column by a reporter for The Los Angeles Times.

NOAO Public Information Officer D. Isbell also served as the leader of the “institutional PIOs” working group at a meeting of NSF-funded public information officers in Socorro, New Mex., in October, 2005. The meeting produced a number of action items for the NSF Office of Legislative and Public Affairs in order to improve its impact.
## NOAO Press Releases Issued in FY2005
### And Associated Media Coverage

<table>
<thead>
<tr>
<th>ID</th>
<th>Date</th>
<th>Title</th>
<th>Media Coverage/Highlights</th>
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<tr>
<td></td>
<td>10/6/04</td>
<td>EF Eri: Mystery Object Neither Star Nor Brown Dwarf (joint w/Gemini)</td>
<td>Reuters wire report on CNN.com, ABC News.com, Yahoo; Space.com, Universe Today.com; New Zealand Herald, <em>Discovery News</em>, and every daily newspaper in Hawaii</td>
</tr>
<tr>
<td>05-01</td>
<td>1/11/05</td>
<td>Flickering Red Giants a Surprising Find [REU student result]</td>
<td>Two major features stories at the Spitzer Science Center Web site; several local newspaper stories in the teachers’ home towns.</td>
</tr>
<tr>
<td>05-02</td>
<td>1/14/05</td>
<td>NOAO-Trained Teachers to Observe with Spitzer</td>
<td>NewScientist.com, Space.com (reposted at Yahoo, MSNBC.com), several Chilean newspapers and numerous French media outlets, Astronomy.com, NASA Astrobiology Web site</td>
</tr>
<tr>
<td>NSF 05-007</td>
<td>1/19/05</td>
<td>Portrait of a Star on the Edge</td>
<td>Associated Press story posted at more than 30 newspapers; also CNN.com, Astronomy.com</td>
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<tr>
<td>05-03</td>
<td>2/15/05</td>
<td>Kitt Peak National Observatory to Host Einstein Day’ on March 12</td>
<td><em>Arizona Daily Star, Tucson Citizen</em></td>
</tr>
<tr>
<td>SSC 2005-08</td>
<td>3/1/05</td>
<td>Exposing Dusty Galactic Hideouts</td>
<td>Associated Press story posted at more than 30 newspapers; also CNN.com, Astronomy.com</td>
</tr>
<tr>
<td>05-04</td>
<td>6/07/05</td>
<td>Kitt Peak to Host Special Evening Program for Deep Impact Comet Event on July 3</td>
<td><em>Arizona Daily Star Tucson section, p 1, Washington Post, various news wires</em></td>
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<tr>
<td>05-06</td>
<td>6/30/05</td>
<td>Kitt Peak Visitor Center to Provide Live Images of Comet Impact</td>
<td><em>Sky&amp;Telescope</em> magazine, CNN.com, KOLD-TV Tucson, Deep Impact Web Site</td>
</tr>
<tr>
<td>05-07</td>
<td>7/8/05</td>
<td>Teachers at Kitt Peak Workshop Obtain Scientific Observations of New Supernova in the Whirlpool Galaxy</td>
<td>Produced four or more daily newspaper stories highlighting the accomplishments of a local science teacher</td>
</tr>
<tr>
<td>05-08</td>
<td>8/30/05</td>
<td>Survey of 4,000 Galaxies Finds ‘Downsizing’ on a Cosmic Scale</td>
<td><em>Podcast by Slacker Astronomy.com,</em> Nature science highlight; posted by Spaceflight Now, <em>Universe Today, PhysOrg.com</em></td>
</tr>
<tr>
<td>05-09</td>
<td>9/12/05</td>
<td>SOAR Telescope First to Observe and Measure Distance to Massive Explosion</td>
<td>Worldwide media coverage, including Science, NPR Radio, Voice of America Radio, USA Today, Reuters, Washington Post, Indianapolis Star, Chicago Sun-Times, Seattle Times, Los Angeles Times, Independent Online-South Africa, China View (Xinhua China); ABC Online-Australia, BBC News, Space.com, <em>International Reporter</em> (India), <em>Chronicle of Higher Education</em></td>
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Special Information Products

Public Affairs produced a variety of special posters, brochures, and handouts in FY 2005, including products related to NEWFIRM, the Dark Energy Camera, new NOAO partnership opportunities, early science from GNIRS, progress on the TMT, and a batch of more than two dozen presentation posters for a special session on the LSST at the January 2005 AAS meeting. A new DVD on the history of Kitt Peak National Observatory was created for sale at the Kitt Peak Visitor Center.

The La Serena daily newspaper El Día published a special eight-page insert section on February 4 with a series of articles and colorful photos describing the value of astronomical research to the region, including PAEO-written stories on CTIO and SOAR.

Web-Based Outreach

NOAO continues to present a timely and lively public “face” on the Internet, changing the featured image on the main home page 29 times in FY05, and adding 18 images to the popular NOAO Image Gallery. New Web sites were created for the Thirty Meter Telescope project (www.tmt.org), the LSST Corporation web pages (www.lsstcorp.org), as well as a Web page to support the Deep Impact event of July 4, which received hundreds of thousands of visitors on the evening of the event, downloading 456 GB of data. The Web pages for the various ASTRO education projects (Project ASTRO, Family ASTRO and ASTRO Chile) and the NOAO Intranet received major redesigns.

Images from NOAO telescopes were highlighted 24 times on the popular “Astronomy Picture of the Day” Web page and were featured nine times on the Space.com “Image of the Day.”

NOAO Web pages had 2.74 mil. unique visitors from October 2004 through September 2005, resulting in 14 mil. page views and more than 60 mil. hits (+10 mil. over the previous 12 months).

PAEO Web Designer M. Newhouse wrote another article for Digital Web magazine titled, “CSS 102:Typography and White Space.” D. Isbell and M. Newhouse began serving as the primary editor and Web designer, respectively, of the new public Web site for the Thirty Meter Telescope project, after submitting a successful proposal to the TMT Board of Directors.

Image and Information Requests

More than 1,100 individual requests to use NOAO images for commercial and non-commercial applications were processed in FY05, including approved requests for use in calendars, amateur astronomy software packages, children’s educational magazines, textbooks, and popular books. Over 8,500 mailings were sent out last year, as well as countless individual responses to requests for information on astronomy and our public programs received via telephone, e-mail, and walk-ins.

5.4 Education and Public Outreach at NOAO South

Undergraduate Research Programs at CTIO

CTIO continued its commitment to astronomy education in FY05 with its two undergraduate research programs, the NSF-funded Research Experiences for Undergraduates (REU: http://www.ctio.noao.edu/REU/reu.html) and the analogous internship for Chilean students, Práctica de Investigación en Astronomía (PIA: http://www.ctio.noao.edu/PIA/). The programs run concurrently for 12 weeks during the Chilean summer (January–March); this greatly enhances opportunities for
cultural as well as scientific interaction among the students, and compared to the U.S. site programs, is not infrequently a determining factor in attracting the best REU applicants to our program. CTIO recently won renewal of the REU award for another five years; the PIA program is entirely funded through the CTIO budget.

Eight exceptional undergraduates were selected for the 2005 program. One of the projects was careful historical photometry of the night sky brightness at Cerro Tololo. This is such an important topic, and the student involved made such a good start on it that he was almost immediately re-hired and spent several additional weeks in La Serena. Another student, working on a more traditional project involving multiple stars, has also returned; his project brings together mentors from Gemini South as well as CTIO and a French graduate student.

Contact has been maintained with many of the REU/PIA alumni. Among our former Chilean students, we have graduate students at the Universities of Toronto and Gottingen as well as Cornell, and one of our 2005 group has been awarded a Fulbright Fellowship to study in the U.S. Two of our 2002 alumni are now working at Las Campanas Observatory.
Ongoing Efforts to Control Light-Pollution

Considerable progress has been made in effecting the changeover of municipal lighting in the area around NOAO South. The most significant step this year has been finding a solution to the financial problems of cash-strapped local municipalities. The central government met with local mayors and worked out a scheme to provide 80% of the financing necessary for local municipalities to make the changeover, thus removing the most significant impediment to proceeding to full compliance with the relevant legislation, DS686, the “norma luminica.”

An article on worldwide efforts to control light pollution, which appeared in the June issue of *Physics Today* with quotes from representatives of both NOAO North and South, highlights the progress made by the town of Monte Patria, as seen in the “before” and “after” views below. Monte Patria is justifiably proud of its status as the first municipality to comply fully with the requirements of the lighting legislation. A recent article by municipal officials in the regional newspaper asserts that “With the inauguration of the new luminaires … which provide greater public safety … we also inaugurated one of the largest investments ever made by the municipality [of Monte Patria]. Today, Monte Patria is the [first] town in the country to comply 100% with Supreme Decree 686 … by changing all its more than 3,700 luminaires.”

The municipality now uses double ballast to drop the power consumption to 60% after the first four hours of operation each night. Light emission is also reduced by about 36% after that time. The Chilean lighting company, Faelec, provided the lighting, and will be paid back by this cash-strapped municipality from the accumulated energy savings: 80,000,000 Chilean pesos per year or about US$150,000 per year. This is particularly important for the long-term protection of Cerro Pachón (home of Gemini South and SOAR) and Cerro Peñón (home of some future large telescopes).

In La Serena, roughly 10,000 new, compliant luminaries have been installed so far (out of a planned total of about 14,000), but the outgoing mayor is reported to have left debts for the current mayor to resolve. At present, the electricity company is cutting power to key municipal installations to protest the failure of the municipality to pay its bills. The changeover was prompted initially by
our emphasis on the need to protect the sky for a local, billion-dollar-a-decade industry—i.e., astronomy. Now the energy shortages—prompted in part by the energy policies of Chile’s natural-gas producing neighbors, Argentina and Bolivia, along with the steeply-rising cost of oil—have helped highlight the need at last to conserve energy. The Ministry of the Economy has included rational lighting policy as one of 12 key points in its national energy plan for the whole of Chile. The policy is being modeled on a gentler version of the “norma luminica” that will encourage the installation of compliant luminaries when the current ones wear out. In the astronomically-sensitive Second (Paranal/VLT–Chajnantor/ALMA), Third (Las Campanas/Magellan) and Fourth (ESO-La Silla/ AURA-Pachón-Tololo regions), the municipalities were given a six-year grace period to come into full compliance.
6.1 Tucson

The downtown Tucson computing facilities continue to evolve as older systems are replaced by newer systems that are more cost-effective and easier to maintain, while providing enhanced services to our computer users. In particular, a new rack-mounted system running FreeBSD was installed in the computer lab to provide NFS (Network File System) services to work stations on our network.

The infrastructure in the Tucson computer lab was continually upgraded to meet the demands of computer installations from NSO/GONG and the NOAO Data Products Program. In FY 2003, three equipment racks were installed in the computer lab for these programs.

The network infrastructure in the downtown Tucson office building was upgraded in FY 2005 to increase performance and reliability. The backbone of the network (three Extreme Networks Summit Ethernet switches linked together) was ripped out and replaced with a single Extreme Networks Black Diamond 8810 switch. Not only does the new backbone switch increase the performance and reliability of the general network, the new switch also allows us to provide a gigabit Ethernet connection to the new generation of Linux and Mac work stations that are appearing on scientists’ desktops. Several additional wireless access points were added to the network to ease the burden on itinerant astronomers. Finally, the processing engine in the Cisco router that connects NOAO-Tucson to Kitt Peak through the DS-3 line and to the Internet through the University of Arizona was upgraded to better handle firewall functions.

Efforts to improve the security and robustness of our network continued in FY 2005. On the e-mail front, we are currently blocking about 250 virus messages per day (down by a factor of 2 from FY 2004) and 3,000 Spam messages per day (down 10% from FY 2004); Spam and virus messages constitute 23% (down from 30% in FY 2004) of our incoming e-mail.

6.2 Kitt Peak

At WIYN, the ICE software on the T2KB data acquisition system (White) was moved to the system Vanilla and White was retired. The functions of the Sparc-20 system Moby were moved to the Linux system Thistle and the Sparc-20 was retired. Disks on the MINIMO data acquisition system (Pearl) were updated. The major upgrade of Hydra was completed, including a new control computer (Oatmeal), software porting to Linux, and software updates. A new motor controller is in development for the WIFOE instrument.

The control computer for OPTIC (used at WIYN and the 0.9-m) was updated with two video boards (supporting three screens) and a 200 GB SATA disk. The software for OPTIC was updated for the 0.9-m TCS.

At the 4-m, an upgrade for the TCS computer was tested and all functions worked except for the CAMAC interface, which will need more development. The upgrade is a Motorola MVME162 replacing a Heurikon V3D.

At the 2.1-m, a new Guider control system will replace the existing CAMAC system. Work was completed on the new control system (hardware and software) and the remaining tasks are the TCS interface and final testing. The 2.1-m observing computer (Lapis) was upgraded from a Sparc-10 to a Sparc-20 and new disks were installed. The old disks and the SBus expansion chassis were removed.

At the 0.9-m, the Mosaic DCA system was upgraded to a Linux computer (Emerald). The old system was a Sun Ultra-2 (Driftwood) which was upgraded to a Ultra-60 and now serves as a spare for Emerald. The S2KB observing computer Taupe was moved to the computer room and the instrument is controlled via VNC on Emerald.
A new filter track encoding scheme was implemented for Mosaic. Also, tests were done for Mosaic auto-focus using low cost frame grabbers.

The DIMM (Differential Image Motion Monitor) system was tested on the sky and is awaiting installation in the Coudé Feed tower.

Mountain-wide, the DVD software was updated to support the DVD+R format. The STB (Save-the-Bits) system was retired and replaced with the DTS (Data Transfer System) feed to the NOAO Science Archive.

### 6.3 NOAO SOUTH – LA SERENA

This has been a year of consolidating our infrastructure—i.e., making systems redundant, replacing older machines, and purchasing spares wherever needed—in order to maintain the system for the next few years on lean budgets. We have also picked up some outside contract work to augment our budget, and are continuing to seek other alternatives. CISS has installed Nagios, a system that monitors all network equipment and servers to alert on failures. The system has been extended to a cellular phone alert and members of the group rotate responsibility for handling the phone and reacting in the event of potential loss of observing time on SOAR or the 4-m.

**Computing**

At the end of last year, we purchased four 2U rack-mounted Linux systems to take over the applications of Web server, Mail server, DNS server and Central User machine. These machines are now functioning with 50% of the mail users moved over from the old server. We are running Postfix and Dovecot to replace Sendmail as our mail transfer agent. This should provide for better security and control over Spam. The master Sun/Solaris DNS machine has been retired and replaced by Linux machines. In fact, all of our Sun computers are now retired except for one that we maintain to support a tape farm for Exabytes, DLTs, and DATs written on Tololo by corresponding Sun systems. To satisfy user home directory backups, we have installed a small Linux server with multiple La Cie terabyte disks, together with software that backs up the user home directories from the machines distributed around the observatory. In the same vein, a Catalog farm has been set up for the Sloan and other catalogs.

Our customized Linux installation system, based on Kickstart, has been used to upgrade the majority of the Linux user machines to the Fedora Core 2 (FC2) version of the Linux operating system (OS). We will most certainly wait until FC5 or 6 to decide on the next major upgrade. Some machines are running FC3 but for special reasons. Fedora seems to have gelled, but the belief is that versions 5 and 6 will show better the future of the OS.

CISS has continued to provide support to the NOAO Data Products Program and continues to maintain the SuperMACHO and SuperNova (SMSN) systems, including the 10-node computing cluster and more than 12 terabytes of disk storage.

A Windows central backup machine has been added for general use. The TrendMicro virus checker has been replaced by a central MacAfee system as the Trend lagged behind updates for recent attacks.

On Tololo, we continue to maintain the old Sun OS systems used by Arcon and have complete systems for sparing. Sun servers are gradually being replaced by Linux systems.

In the 4-m console, there is now a central observers machine for vnc connection to the various individual instrument data-taking machines connected via a gigabit connection.
Networking

The major event of external networking was the renegotiation of the Internet2 (I2) connection from Chile to the U.S. The result was that we increased our bandwidth to 45Mbps from the original 10Mbps we had over the last three years (funded through a joint NSF grant to Gemini and NOAO). The circuit is provided by REUNA from La Serena to Santiago and by Florida International University (FIU) from Santiago onwards to Miami where they connect to the Atlanta Internet2 POP. This is a five-year contract with FIU and an open contract with REUNA, which will carry us into the DECam installation.

Our internal microwave backbone between La Serena and both Cerro Tololo and Cerro Pachón has been configured as dual OC-3 circuits, changing the “hot spare” channel into an active channel, while preserving the automatic failover in the case of a failure in one channel. While the backbone Microwave system has seen some repairs to the towers and the antennae, zero downtime has been enjoyed on the link due to the radios.

A straw man voip system has been installed between SOAR and La Serena, in principle for SOAR, though it may be extended to a broader usage. The object is to connect the system to the PBX, but the plant is old and needs significant funds to install the necessary interface for an E-1 connection.

VPNs have been set up in La Serena, Tololo, and SOAR for remote access, which is our preferred method for clients to enter the system when traveling.

Taking advantage of excess Cisco equipment to be found on Ebay, we have totally spared all our network equipment in La Serena, Tololo, and SOAR and augmented some systems at reasonable cost.

The 4-m on Tololo now has a redundant Cisco 6500 switch that isolates the 4-m from the rest of the mountain now that we have finished the IP re-numbering. This provides gigabit networking to whatever machine is capable of that speed. SMARTS, AOSS, and PROMPT are served by Cisco 5500 switches at 10/100Mbit.

The Panchromatic Robotic Optical Monitoring and Polarimetry Telescopes (PROMPT) project has installed six telescopes that are now connected by a new fiber running off the summit. A central enclosure has been constructed in that area to maintain PROMPT and other new users to Tololo. The PROMPT project transmits GRB observations from these robotic telescopes through the newly-installed network infrastructure (from local fibers to our new international link) back to the University of North Carolina for immediate analysis. We continue to work with the University of North Carolina and the University of Michigan to set up VPNs and security for remote observing.

Other

Las Campanas has contracted our services to maintain their system and network administration. A large amount of equipment has been recommended, which is now being purchased in order for us to upgrade their system and remotely monitor their systems from La Serena. Several Linux machines have already been upgraded with FC4. A possibility exists that we may also provide some computer support to Gemini, but that is still being negotiated.