NATIONAL OPTICAL ASTRONOMY OBSERVATORIES

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ANNUAL REPORT

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# NOAO ANNUAL REPORT 1997-1998
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I. INTRODUCTION

This report covers the period 1 October 1997 to 30 September 1998.

The National Optical Astronomy Observatories (NOAO) are operated by the Association of Universities for Research in Astronomy, Inc. (AURA), for the National Science Foundation (NSF). The four divisions of the NOAO are: the Cerro Tololo Inter-American Observatory (CTIO) in northern Chile; the Kitt Peak National Observatory (KPNO) near Tucson; the National Solar Observatory (NSO) with facilities on Kitt Peak and at Sacramento Peak, New Mexico; and the US Gemini Program (USGP)/Science Operations (SCOPE) based in Tucson. NOAO observing and data reduction facilities are available to the entire astronomical community. The NOAO Home Page contains on-line information about NOAO services, including telescope schedules and instrument availability, and information about how to apply for telescope time. The NOAO Home Page can be accessed through the World Wide Web at http://www.noao.edu/.

II. AURA BOARD

AURA is a private, non-profit corporation that operates world-class astronomical observatories through its “operating centers.” NOAO is an operating center managed by AURA under cooperative agreement with the NSF. There are thirty-one AURA member institutions, including four international affiliates. The member institutional representatives elect a governing Board of Directors of thirteen members, which includes the President, ex-officio. In addition to NOAO, AURA operates and manages the Space Telescope Science Institute under contract with NASA, and the International Gemini Project under cooperative agreement with the NSF on behalf of seven partner countries. More information on AURA and its organizational structure can be found at http://www.aura-astronomy.org/.
III. SCIENTIFIC PROGRAM

Several hundred papers are published each year using data obtained from NOAO. A sample of recent work is described in the following section.

A. Cerro Tololo Inter-American Observatory (CTIO)

In the past year, CTIO has received much attention in the scientific and popular press over two scientific projects that span the full range of the sizes of structures in the Universe: planet formation and the overall geometry of the Universe. In both cases the scientific groups have come to CTIO to use the observatory because of its excellent sky conditions and infrastructure. The planetary disk search requires excellent atmospheric thermal conditions and low perceptible water column depths. The supernova searches require large format mosaic CCD detectors and guaranteed clear weather to provide supernova candidates to be available for observations around the world.

1. Observational Evidence from Supernovae for a Cosmological Constant and an Accelerating Universe

The Hubble diagram, which plots the luminosity-redshift relation for objects believed to be “standard candles,” provides compelling evidence for the expansion of the Universe. Locally, the expansion appears to be linear, but the time evolution of the expansion rate should depend directly on the contributions of various energy densities to the mix. While the Universe is known to contain a significant amount of “pressureless” matter, $\Omega_m$, which works to decelerate the expansion, its dynamics may also be significantly affected by more exotic forms of energy. Pre-eminent among these is a possible energy of the physical vacuum, $\Omega_v$, or Einstein’s “cosmological constant,” whose negative pressure would work to accelerate the expansion.

Type Ia supernovae (SNe Ia), which are thought to arise from the thermonuclear explosion of a carbon-oxygen white dwarf, offer an attractive possibility for standard candles because of their extreme luminosity ($M_B \sim -19.5$) and relatively homogeneous light curves and spectra. Although observations over the last ten years have shown that SNe Ia are not all the same luminosity, work carried out at CTIO by the Calán/Tololo Supernova project (see summary in Hamuy et al. 1996, AJ, 112, pp. 2391, 2398, 2408, 2438) has shown that the luminosity correlates tightly with a single parameter, the observed decline rate of the light curve. These corrections, along with reddening corrections based on the multicolor light curves (Riess et al. 1996, ApJ, 473, 88) allow the measurement of the distance modulus to the supernova at a precision of ~ 15%.

During the past three years, two international groups—the High-Z Supernova Search Team led by Brian Schmidt (Mt. Stromlo and Siding Spring Obs.) and the Supernova Cosmology Project headed by Saul Perlmutter (Lawrence Berkeley Labs)—have independently made extensive use of the CTIO Blanco 4-m telescope to carry out searches for high-redshift SNe Ia in order to determine or constrain $\Omega_M$ and $\Omega_v$. The supernovae are discovered by observing dozens of high galactic latitude fields with the Blanco 4-m just after a new moon. The field of the BTC CCD mosaic camera, developed by Tony Tyson (Lucent Technologies) and Gary Bernstein (U. of Michigan), contains hundreds of galaxies at redshifts between 0.3 and 1.0. Just before the next new moon, the same fields are re-observed and the images are compared, thus checking tens of thousands of high redshift galaxies. Rapid data analysis makes it possible to identify the supernovae within hours of the observation so that the follow-up photometry and spectroscopy can begin immediately.
Since other telescopes such as ARC, HST, and Keck must be scheduled for follow-up observations well in advance of the discovery of the supernovae, the projects must guarantee objects to observe. This is why both groups have relied on the CTIO 4-m Blanco Telescope to find all the supernovae. During the Chilean summer months, the CTIO site has excellent seeing, and the nightly skies are ~ 80% photometric and ~ 90% spectroscopic. To date, over 150 supernovae of all types have been discovered by both groups with the CTIO 4-m Blanco Telescope.

The High-Z Supernova Search Team and the Supernova Cosmology Project announced their latest results at the January 1998 meeting of the American Astronomical Society and at a symposium on Dark Matter held at UCLA on 18-20 February. The High-Z Supernova Search Team has since submitted a paper to the Astronomical Journal (Riess et al. 1998). Seemingly in defiance of common sense, the expansion of the Universe appears to be actually accelerating at present, rather than slowing down as would be expected if gravity were acting alone. Stated in more precise terms, a non-negligible positive cosmological constant is strongly preferred at the ~ 2.5 - 5 σ level, depending on the analysis used. For a spatially flat Universe (i.e., \( \Omega_M + \Omega_\Lambda = 1 \)), the High-Z Supernova Search Team finds that a best fit to their nine best-observed, high-redshift SNe Ia implies \( \Omega_\Lambda = 0.76 \pm 0.11 \) and \( \Omega_M = 0.24 \pm 0.11 \); the Supernova Cosmology Project derives essentially identical values from a larger sample of 40 high-redshift SNe Ia. Even if the cosmological constant, \( \Lambda \), is forced to be zero, both groups find that at the > 5 \( \sigma \) level that there is not enough mass in the Universe to halt the eventual expansion—i.e., we live in an eternally expanding Universe.

How can we escape these conclusions? The data show that the high-redshift SNe Ia are observed to be 0.2-0.3 magnitudes dimmer than expected, even in the case of an empty Universe. To explain this effect without using cosmology, there would have to be systematic errors of this size in the data. An assumption implicit in this work is that the range in properties of Type Ia supernovae observed at high redshift are the same as those observed at present epochs. From work carried out at CTIO by Hamuy et al. (1996), we know that the local sample of SNe Ia displays a weak correlation between peak luminosity and host galaxy type in the sense that the most luminous SNe occur in late-type galaxies. In addition, the SN Ia rate per unit luminosity is almost twice as high in late-type galaxies as in early-type galaxies at the present epoch. Both of these observations suggest that a population of progenitors exists in late-type galaxies which is younger and gives rise to brighter SNe Ia than those contained in early-type galaxies, which in turn could indicate an evolution of SNe Ia luminosities with progenitor age. Recent theoretical work by Höflich et al. (1998, ApJ, 495, 617) also suggests that there may be observable differences in the light curve shape, luminosity, and spectral characteristics of SNe Ia as a function of the initial composition and metallicity of the white dwarf progenitor. However, the range of age and metallicity of SN Ia progenitors in the nearby sample is likely to be larger than the average change in these quantities over the 5 Gyr look-back time to the high-redshift SNe (to \( z \sim 0.5 \)). Thus, to first order, there is reason to expect that the relation between light-curve shape and luminosity that holds for the range of stellar populations encountered in the late-type and early-type host galaxies in the local sample of SNe Ia should also be applicable to the range of stellar populations encountered in the hosts of the distant SNe.

The low matter density and positive cosmological constant also may help resolve another cosmological problem: the age of the universe. The dynamical age of the Universe based on the high-z supernova data anchored by the Cepheid distances to nearby host galaxies of Type Ia supernovae as published by Saha, Sandage, and collaborators is \( \sim 14 \pm 1.5 \) Gyrs. This is consistent with the age of the oldest stars in our Galaxy. The same data set, which is dominated by the lower-z supernovae from the Calán/Tololo survey, gives a Hubble constant of \( 65 \pm 1.3 \) (statistical) \( \pm 3.0 \) (external) \( \text{km s}^{-1} \text{Mpc}^{-1} \).
2. The Discovery of a Planet-Forming Disk Around a Young Star

A team of astronomers, using the University of Florida mid-IR camera/spectrometer "OSCIR" on the CTIO 4-m Blanco telescope, has discovered a disk around a nearby star that may be forming—or may have already formed—planets. The discovery was made by a team comprised of Ray Jayawardhana, Lee Hartmann, Giovanni Fazio (Harvard-Smithsonian Center for Astrophysics), Scott Fisher, Charles Telesco, and Robert Piña (U. of Florida). The dust disk was also discovered independently and simultaneously by a second group using the Keck II 10-m telescope.

The newly discovered disk surrounds HR4796A in Centaurus. The disk is roughly 250 AU across and is seen nearly edge-on in the "OSCIR" 20 μm images. It is much younger than the Beta Pictoris disk—10 million vs. 200 million years old—and is the right age for planet formation. The binary companion HR4796B is 500 AU from the primary. The composite nature of this system suggests that the presence of a companion star does not necessarily disrupt a disk before it has had enough time to form planets.

From previous work by Michael Jura at UCLA and colleagues, it was known that a dust cloud with a central hole surrounded the primary star. The OSCIR images show that the cloud is indeed a disk. The hole may be due to gravitational clearing by inner planets. The disk truncation at 125 AU radius may represent a similar effect due to the companion. A definitive test of this possibility requires an improved determination of the binary orbit.

The disk is fainter at 10 μm than at 20 μm, but is undetectable at 2 μm, the longest working wavelength of many near-IR cameras. OSCIR's 128 x 128 Si:As Rockwell array represents a major advance in mid-IR detector technology which, together with the superb imaging qualities of the Blanco telescope, made this discovery possible. Telesco and colleagues at the University of Florida built OSCIR. It is available as a facility instrument at CTIO through a collaborative agreement, with technical support provided by the Florida group. "This discovery is a particularly exciting example of the science enabled by the NSF through the National Astronomy Centers," says Hugh Van Horn, Director of NSF's Division of Astronomical Sciences. In this case, the cooperation between the University of Florida and CTIO is making this innovative instrument available to all US astronomers. The research of both discovery teams was supported in large part by the NASA Origins Program, with additional support to the CfA/Florida team from NSF, NOAO, and the Smithsonian Institution.

B. Kitt Peak National Observatory (KPNO)

1. Giant Flows from Low-Mass Stars

Bipolar, jet-like flows associated with young, intermediate mass stars have been assumed to be quite local to the environment of the star, only a fraction of a parsec in length. Reipurth, Bally, and Devine (1997, AJ, 114, 2708) have changed that view through discovery of a number of connected outflow complexes associated with young stars that extend for a number of parsecs. The largest of these Herbig-Haro flows is HH 111, which extends some 7.7 pc from its associated star. The discovery of giant HH outflows such as HH 111, which spans nearly a degree on the sky, required the unique capability of wide-field telescopes equipped with large format CCDs—the Curtis Schmidt at CTIO and the Burrell-Schmidt and 0.9-m at KPNO were critical to their investigation—as some of these complex outflows were formerly thought to be unconnected HH objects but shown to be related by their panoramic, narrow-band imaging. Spectroscopic verification of the systematic, bipolar nature of the flow was obtained with long-slit spectroscopy at the KPNO Mayall 4-m. Giant flows with ages comparable to the duration of the accretion phase of the stellar sources provide a record of the star's mass loss and accretion history. Many of these giant HH flows have punched through their parent clouds and are injecting significant energy
and momentum into the interclump medium, with associated contribution to the UV radiation field and
dissociation of interclump molecules.

2. **A Supernova from Half the Age of the Universe**

Type Ia supernovae are proving to be powerful probes of cosmological world models. Supernovae close
to us show that the Hubble flow is impressively linear. Those further away permit the deceleration of the
Hubble flow over the age of the universe to be observed, in turn providing unique constraints on the
matter density of the universe and the cosmological constant. The method is first to find supernovae in
regions of “blank sky,” and then follow their light curves to allow for small variations in their intrinsic
luminosities to be calibrated. Hubble diagrams of apparent supernovae as a function of redshift then
provide probes of Omega and Lambda (the mass density and cosmological constant, respectively). Many
of the supernova discoveries and light curve observations have been made at NOAO facilities, and have
shown great promise in measuring cosmological parameters. Key to this approach is finding supernovae
at large enough redshifts so that cosmological effects are large, and conclusions are invulnerable to small
systematic or random errors.

Saul Perlmutter (Lawrence Berkeley) and his extensive set of collaborators used the CTIO 4-m telescope
to discover a Type Ia supernova at redshift $z = 0.83$, presently the highest redshift supernova known.
Perlmutter and collaborators obtained follow-up observations of its light curve using the WIYN and
CTIO 4-m telescopes (as well other groundbased telescopes and HST). At $z = 0.83$, the universe was
roughly half of its present age. Cosmological effects strongly dominate at such look-back times; thus this
supernova is an especially important datum. Its brightness cleanly falls on Hubble diagrams requiring the
universe to be open, ratifying earlier work done by Perlmutter and collaborators.

One important concern is whether supernovae at that epoch can be fairly compared to those seen in more
recent times; evolutionary effects have been the shoals on which many previous cosmological tests have
foundered. Perlmutter et al. find the light curve to be completely normal, however, once its shape is
corrected for the substantial time dilation expected; spectra obtained with the Keck II telescope also
show the supernova to be unexceptional compared to those at the present epoch.

3. **No Evolution Seen in the X-ray Luminosity Function of Galaxy Clusters**

Clusters of Galaxies are the most massive virialized structures in the universe. Clusters of galaxies can be
detected at times when the universe was less than half of its present age. Understanding how clusters of
galaxies have evolved since that time tells us if significant formation of these dense systems is still taking
place, an issue which is directly related to the matter density of the universe. Studying the evolution of
galaxy clusters, however, requires generating a complete sample of clusters over an extended redshift
range, work that is now underway by a number of groups using differing methods. One key way to search
for clusters is by their X-ray emission, since this is a direct marker of the deep potential wells that bind
the clusters together. This is of additional interest as work done earlier in this decade on X-ray selected
samples of clusters appeared to show “negative evolution,” that is, present epoch clusters of galaxies
were brighter in X-ray emission than their cosmologically earlier counterparts. This would suggest that
growth and formation of clusters continues today. Testing this issue has been central to exploring the
evolution of galaxy clusters.

Piero Rosati (STScI) and collaborators have used the KPNO 4-m to identify a complete sample of galaxy
clusters with the aim of studying the cosmological evolution of the cluster X-ray luminosity function.
Rosati et al. drew their initial set of candidates from deep-pointed ROSAT observations. Images at the 4-
m were then used to identify galaxies within the X-ray selected cluster candidates, followed by spectros-
copy, again using the KPNO 4-m, to complete identification of the clusters and to obtain their redshifts. Overall, Rosati et al. identified 70 galaxy clusters with redshifts out to \( z = 0.8 \). Careful selection of the initial X-ray defined sample, plus thorough optical follow up of the cluster candidates, has enabled Rosati et al. to construct the X-ray cluster luminosity function over the last half of the age of the universe. Significantly, Rosati et al. find that no evolution of the X-ray luminosity function has taken place, in contrast to the earlier work mentioned above. This result now serves as an important constraint for understanding how the largest structures in the universe were formed.

C. National Solar Observatory (NSO)

1. Solar Oblateness and Brightness

Measurements of the shape of the Sun, and in particular the solar oblateness, have been published and debated for nearly a century. An unexpected capability of the Michelson Doppler Imager aboard the Solar and Heliospheric Observatory (SoHO) has been the ability to determine precisely the solar limb shape and brightness. The stable thermal environment of the SoHO experiment at the L1 Earth-Sun Lagrange point has allowed NSO scientists, in collaboration with Stanford and Lockheed experiment PI's, to obtain the most accurate measurement of the solar oblateness and hexadecapole shape terms. From an experiment performed in March 1998 where the SoHO spacecraft was rotated in fixed angular increments around the telescope axis, the difference between solar equatorial and polar radii associated with the static oblateness was derived to be \( 8.07 \pm 0.58 \) milliarcsec. For the first time a significant hexadecapole \((l = 4)\) solar shape distortion of \( 1.4 \pm 0.54 \) milliarcsec was also determined. The measured oblateness tends to rule out the possibility of a rapidly rotating solar core, although it is not yet clear if the derived hexadecapole shape is consistent with "standard solar models." An extra bonus from the solar limb astrometry experiment has been a precise determination of solar latitudinal color temperature variations. The March experiment also confirmed earlier groundbased experiments that indicated that the solar photosphere is about 1 degree hotter near the poles and equator than it is near mid latitudes. A peculiar 1-degree dip in the photospheric temperature in the immediate vicinity of the poles was also detected.

In a related analysis, the time-variable limb shape (on timescales from minutes to hours) appears to be dominated only by statistical noise sources down to limb shape change amplitudes of a few microarc-seconds. Analysis of an early one-month sample of SoHO/MDI data rules out the possibility of solar g-modes with corresponding surface velocity amplitudes larger than a few mm/s.

2. Stratospheric HCl and Ozone

Groundbased spectroscopic observations of the Sun contain countless absorption lines due to the Earth's atmosphere in the infrared. Systematic observations of trace gases such as CO\(_2\), CH\(_4\), N\(_2\)O and CO began in 1977 at Kitt Peak and at the Jungfraujoch. The concern was and is global warming. Then came the warning by Molina and Roland that free chlorine in the stratosphere would catalytically destroy our protective ozone layer. Anthropogenic halocarbons, the so-called CFCs, are the primary source of such chlorine and one way to monitor its presence is by means of an unblended line of HCl at 3.4 microns. The trace gas archives showed that this HCl line was increasing in strength rapidly. No information, however, seemed available prior to 1977.

In 1969-1970 Don Hall was making his pioneering exploration of the near-IR spectrum of the photosphere and sunspots using a remarkable grating ruled at MIT. A search was made of Hall's archive tapes that were stored in the NOAO basement. Many tapes were no longer readable but one that was, for September 1971, contained a high signal/noise profile of the HCl line. When this profile was measured by the same method used for recent observations, a 25-year record of HCl emerged. It was evident that
the line has increased by a factor between three and four, and there is little evidence for a slowdown as might be expected from the Montreal Protocol. These results appear in *Geophysical Research Letters*, 24, No. 19, p. 2363, October 1, 1997.

### 3. Helioseismic Holography of “Acoustic Moats”

Helioseismic images of active regions computed by C. Lindsey and D. Braun (SPRC) show remarkable acoustic anomalies surrounding all large sunspots. Lindsey and Braun are applying a computational technique they call “solar acoustic holography” to SoHO-MDI observations of active regions. The resulting acoustic images show conspicuous halos, up to 100,000 km in diameter surrounding large sunspots. Lindsey and Braun believe that these acoustic moats are the helioseismic signature of rapid surface outflows surrounding the sunspots. The acoustic moat appears to be the result of Doppler scattering, by the subsurface outflow, of an acoustic deficit induced at the solar surface by the nearby sunspot.

Depth analysis, based on focus-defocus diagnostics of the image coherently extrapolated to focal planes at various subsurface levels, show the acoustic perturbations signifying both the sunspot and the acoustic moat to be predominantly superficial, within a few thousand km of the solar surface. Acoustic moats often have sharp outer boundaries. Careful comparisons with Kitt Peak magnetograms show that these are sometimes marked by magnetic regions.

Following theoretical work in the 1970s by F. Meyer and colleagues, Lindsey and Braun propose that the acoustic moat is the helioseismic manifestation of an anomalous convection eddy that is driven by heat accumulation resulting from the local blockage of convective transport through the sunspot photosphere. With the advent of SoHO and GONG, helioseismic holography promises considerable insight into the general subject of convective flows surrounding sunspots, an issue that is certain to be critical to the long standing problem of thermal transport in the neighborhoods of sunspots.
IV. DIVISION OPERATIONS

A. CTIO OPERATIONS

Telecope Upgrades and Instrumentation

CTIO continues to improve the performance of its telescopes and to provide them with state of the art instrumentation, so that they remain scientifically productive in the era of 8 to 10-m telescopes. In particular, the Blanco telescope is being re-instrumented so that it will complement the capabilities of the Gemini 8-m and the SOAR 4-m telescopes, both under construction on Cerro Pachón. Along with a possible new 2.5-m wide-field telescope, the Blanco 4-m will provide the wide field capability essential to the efficient utilization of Gemini. Significant use of CTIO scientific and technical resources is being made as part of the SOAR project, and to a lesser extent for Gemini. During FY 1998 CTIO supported two Scidar runs by Gemini staff at the 1.5-m telescope, in order to characterize the vertical turbulence profile of the atmosphere. Knowledge of the turbulence profile is a prerequisite for the design of the Gemini South adaptive optics system.

1. Blanco 4-m Telescope

A main focus in FY 1998 continued to be the instrumentation and facility upgrades to the Blanco 4-m telescope, building upon the improved image quality now routinely delivered as a consequence of optical and thermal improvements made in the recent past. The f/14 tip-tilt secondary gives CTIO the only such capability for IR work in the Southern Hemisphere, apart from the ESO VLT. The commissioning of the tip-tilt system was completed during FY 1998, and it is now in routine use with the imagers COB and CIREM, and with the IRS. The fast (100 Hz) guide camera has produced images in the K band (2.2 μm) as good as 0.3 arcsec FWHM, where the image floor appears to be set by telescope optics aberrations. In general, improvements of 0.2-0.3 arcsec are seen with the system operating. Development is continuing.

The IMAN Shack-Hartmann image analyzer is being adapted for use at f/14, which will allow removal of the residual aberrations with the primary mirror active control system. In addition, electronics are being upgraded and new software algorithms are being developed; these will be tested and installed in FY 1999 along with a small, high-quantum-efficiency EEV CCD. Substantial improvements in the limiting magnitude of useable guide stars are expected, along with better correction in general.

The Delta-Tau mount servo controllers have been installed and tested in several engineering runs throughout the year. These tests have been very successful, with the telescope now controllable at all speeds, using the incremental encoders to close the servo loop. Final tests and commissioning will take place at the beginning of FY 1999; the new servos will provide a modern and maintainable system with potential for improved performance in pointing, tracking, and guiding.

In preparation for the commissioning of the Hydra Multi-Object spectrograph in FY 1999, a large multi-element optical corrector with ADC was installed at the f/8 R-C focus. This gives a highly corrected field over almost one degree diameter, at any zenith distance up to 70 degrees. A particularly notable feature is that the complete optical assembly can be swung out of the beam when IR instruments are installed, yet can be returned to its original position within a few microns when required for use with optical instruments.

The BTC 4K x 4K Mosaic Imager, provided by A. Tyson (Lucent Technologies) and G. Bernstein (U. of Michigan) has been a highly popular and successful instrument since its introduction last year. The loan agreement was recently extended to the end of Semester 1999A. Two of the CCDs were replaced during the year with improved devices, offering better cosmetics and linear response. Several large (6 x 6 inch)
optical filters were purchased; these can also be used with the Mosaic Imager II when it replaces the BTC in FY 1999.

OSCIR, the mid-IR imager-spectrograph built by C. Telesco (U. of Florida), has seen steady use throughout the year. The loan period has been extended for a further year, the strong science case outweighing the logistical difficulties caused by the need to use the f/30 chopping secondary.

2. Major Instrumentation Efforts

Much of the instrumentation development work at CTIO during FY 1998 has been related to preparing for the major new instruments about to be commissioned at the Blanco telescope. The first of these is Hydra. Apart from the corrector, mentioned above, a bench spectrograph has been built, with a new camera, and a comparison lamp assembly installed. The multi-object positioner and fiber assembly were built by IPG in Tucson, with a major part of the software effort being undertaken by CTIO.

The NOAO Mosaic I imager at KPNO recently had its Loral CCDs replaced with thinned SiTe CCDs, and a copy of this instrument, Mosaic II, is scheduled to be commissioned at CTIO during FY 1999. Both instruments use Arcon CCD controllers, and the primary electronics activity at CTIO this year has been the construction and testing of the controllers for Mosaic II. Hardware and software support for Mosaic I, both in its operations phase on the Mayall 4-m telescope at KPNO, and in its CCD upgrade, have been provided by CTIO.

A three-year loan of the upgraded OSIRIS, the Ohio State U. IR spectrograph-imager, was negotiated. Before coming to CTIO, OSIRIS will be fitted with a Rockwell 1K x 1K HgCdTe array, and associated opto-mechanical modifications will be made. These upgrades are being funded by CTIO, which will retain ownership of the array. Being a versatile multi-mode instrument with two plate scales, OSIRIS is well suited to taking advantage of both superb and median image-quality conditions. It will replace COB, CIRIM, and IRS for almost all programs. High-dispersion spectroscopy is an exception that requires the IRS. This instrument was successfully converted from f/30 to f/14 during FY 1998, in order to gain throughput through use of the tip-tilt secondary.

The high-resolution IR spectrometer Phoenix, constructed by IPG in Tucson, was originally scheduled to be commissioned at CTIO during FY 1998. It has been delayed a year, and is now expected at CTIO late in FY 1999. Phoenix will eventually be shared by NOAO and Gemini.

3. SOAR 4-m Telescope Project

CTIO is deeply involved with most scientific, instrumental, and operational aspects of SOAR.

- Site Preparation
  A site 400m NE of the Gemini South telescope on Cerro Pachón has been selected. The site was leveled off and an access road constructed in early 1998. A small geotechnical study is currently underway to finalize the positioning of the foundations for the SOAR building.

- “Laying of the Foundation Stone”
  A brief ceremony was held in mid-April to launch the visible part of SOAR project activities on Cerro Pachón, followed by a luncheon on Cerro Tololo. This simple event was attended by about sixty people including senior representatives of each of the SOAR consortium members, Brazil,
NOAO, UNC, and MSU. The stone itself was lowered into position at the site by Sidney Wolff, Director of NOAO, acting in her capacity as Chair of the Interim SOAR Board.

- **Building Design and Construction**
  A conceptual building design has been completed by the SOAR project architect, and reviewed with staff at CTIO concerning operational aspects. A Memorandum of Understanding between CTIO and the SOAR project team is being drawn up, with a view to having CTIO serve as general contractor for the SOAR telescope building.

- **Software and Instrumentation**
  The top-level software design was provided by CTIO for the SOAR CoDR, and further software and hardware oversight and consulting work is anticipated throughout the life of the project. Oversight will also be provided in the design and construction of the instrument adaptor assemblies, which will be fabricated in Brazil. Preliminary discussions regarding the use of the ARCON CCD controllers for SOAR optical and IR instruments have taken place with the project team.

  A Letter of Intent was submitted by CTIO for the design and construction of the SOAR Optical Imager. The Imager includes an f/16 to f/9 focal reducer, a UV transmitting ADC, and tip-tilt probe. It images onto a 4K x 4K CCD mosaic, with pixel scale designed to take full advantage of the superb image quality expected for the SOAR telescope.

4. **CCD Implementation and ARCON Controller**

Development of the ARCON CCD controller for the Mosaic II Imager continued, in parallel with upgrades for the video, ADC, and VTT cards. Design and fabrication of the cards have been completed, and testing is in progress, with the aim of upgrading the boards in existing controllers at CTIO and KPNO during FY 1999. The new boards offer higher speed, greater reliability, and improved control and status.

The STIS 2K x 2K CCD at the Schmidt was replaced by a similar device previously used at the KPNO Burrell-Schmidt Telescope. The original CCD was re-coated with a laser dye layer, but the coating de-laminated after only a few temperature cycles. Options are being considered for replacing this CCD with a higher quantum-efficiency device during FY 1999.

5. **Existing Small General-User Telescopes on Cerro Tololo**

During FY 1998 work on improving the thermal environment of the 1.5-m telescope was completed. Insulation was improved on the main floor, inefficient power transformers were replaced, and air conditioning units were installed. These changes are in addition to earlier modifications to the dome itself, where large louvered windows allow airflow through the structure during observing.

6. **New "Tenant" Installations and Upgrades**

- **Swarthmore 0.3-m Robotic H-alpha Camera**
  This instrument was installed on Cerro Tololo by a group led by John Gaustad (Swarthmore College) and is being used to carry out an H-alpha survey of the entire southern sky with a resolution of 45 arcseconds per pixel. The system is fully autonomous, only requiring intervention by CTIO staff at weekly intervals to change data tapes. Routine science operations began in November 1997. The survey had reached 50% completion by August 1998 and the data collection is expected to be
finished by November 1999. Further information on this survey and its science goals, together with a
detailed description of the instrument, can be found at: http://www.astronomy.swarthmore.edu.

- **2-MASS**
  The Southern 2MASS telescope was installed at Cerro Tololo in December 1997 and optically
  aligned a month later. The infrared survey cameras were integrated with the telescopes in early
  March and routine survey observations began two weeks later on 19 March 1998. According to the
  2MASS project manager the responsiveness of the CTIO staff was instrumental in the swift
  commissioning and subsequent smooth operation of the facility. To date the facility has observed
  over 5000 square degrees (or 25% of the sky south of the Equator). The quality of the data is
  excellent. The good seeing at Cerro Tololo routinely yields images of better quality than the best
  images observed at the Northern Hemisphere observatory at Mt. Hopkins. The sensitivity and
  positional accuracy of the data meet or exceed the survey’s specifications (3-sigma sensitivity is
  better than 17.1, 16.4, and 15.6 mag at J, H, and K respectively. Positional RMS is less than 0.5 arcsec
  from the Hipparcos/Tycho reference frame). Pipeline processing of 2MASS data at IPAC began in
  June 1998, with initial processing focused on Northern Hemisphere data. Routine pipeline processing
  of Southern data will begin in September. The 2MASS project’s home page is located at
  http://pegasus.phast.umass.edu/.

- **YALO**
  The Yale 1-m telescope was closed for about a year as a result of cuts in NSF funding for small tele-
  scopes at the National Observatories. It was re-opened in May 1998 thanks to a fundraising effort by
  the international YALO consortium (in which NOAO maintains a 10% share). This telescope
  provides access, by NOAO users, to interesting synoptic monitoring capabilities. Further details can

- **GONG**
  CTIO is one of the six worldwide sites housing the solar Global Oscillation Network Group. A report on
  this group’s activities can be found elsewhere in this report and at: http://www.gong.noao.edu/index.html.

- **USNO**
  The survey for the United States Naval Observatory’s CCD Astrographic Catalog continues to progress
  well. A summary of the aims of the survey can be found at: http://www.noao.edu/noao/noaonews/mar98/
  node3.html.

7. Other Activities

- **Light Pollution Control**
  Work has continued during the year on combating light pollution at national, regional, and municipal
  levels. Further details have been made accessible in Spanish via CTIO’s home page: http://www.ctio
  .noao.edu/light_pollution/.

- **New Support Services**
  During the year the Logistics and Administrative Services Division of CTIO has been preparing to
  separate from CTIO in order to take on its new role as the AURA Observatory Support Services
  (AOSS) unit of AURA’s Observatory in Chile (AURA-O). AURA-O in Chile will include Gemini
  South. CTIO, SOAR, 2MASS and the other smaller tenant facilities.
A major drive has been to complete integration of CTIO’s local accounting and business administration software into the new CASNET system at NOAO, while working closely with Gemini and the other units of AURA-O so as to ensure compatibility with their accounting systems. This overall upgrade is proving to be an essential and successful step forward in support of AURA’s many new activities in Chile.

The AURA Observatory Support Services (AOSS) unit will have no budget of its own, but will depend on service agreements with the other units of AURA-O.

B. KPNO OPERATIONS

The major emphasis of the programs at KPNO during this year was on improvements to the image quality at the 4-m Mayall telescope; continued operation of the WIYN telescope; and the initial scientific operations of two major new instruments: a mosaic imager for optical work and a high resolution infrared spectrograph.

1. Image Quality Improvements

This year we continued to make substantial efforts to improve the delivered image quality (DIQ) at the 4-m Mayall telescope. Nightly seeing measurements show that the median DIQ is 1.1”, considerably higher than the 0.8” achieved by WIYN. What causes this difference? Local thermal effects and uncompensated optical aberrations are both likely to be playing a role.

In past years we implemented a cooling system that blows chilled air onto the front surface of the primary mirror and a dome air-mixing fan to move cold air from the floor chillers up to the upper part of the dome in order to maintain a more isothermal environment.

Temperature differences between the dome air and outside air significantly degrade the DIQ. The two-year Kitt Peak project completed this year was the installation of dome vents at the 4-m. These vents provide an additional 1600 ft² of open area. In a 10 mph wind, there are between 100 and 300 flushes of the dome each hour, depending upon the direction of the wind relative to the dome. We believe that this air exchange has alleviated many, if not all, of the thermal problems within the dome.

In addition, careful attention is being paid to the telescope optics. Wavefront studies are now used routinely to assure proper collimation. These studies suggest that even when the telescope is fully collimated, the DIQ is degraded by more than 0.1” from astigmatism and other low-order bending modes of the primary, seen particularly away from the zenith. In FY 1998, we designed and installed a system of active primary mirror support to remove this contributor to the DIQ. The original system for the primary support was based on two rings of pneumatic pads. The air pressure was regulated separately for each ring, but no non-axisymmetric force application was possible. The new system can actively regulate the air pressure on each pad, with a readback for the applied force through a force transducer. Manual valves can convert the system back to its previous passive mode. The end of this fiscal year will see the 4-m back in operation in passive support mode. During the course of the fall observing semester, the force matrix will be calibrated for observing at the different foci of the telescope, and the active correction will be applied through look-up tables for subsequent runs.

To re-plumb the primary mirror cell, the bottom end of the telescope had to be thoroughly disassembled. The primary mirror was re-aluminized, as were the secondaries. A new, more accurate encoder was installed on the Cassegrain rotator, which will be an aid for both long-slit and multi-slit spectroscopic observations. The electronics crew also took the opportunity to clean up the cable wrap after the final removal of CAMAC and other no longer used systems.
2. WIYN Queue Observing Experiment

The WIYN Queue observing experiment completed its third year of operation in 1998. Semester 1998A marked completion of the second year for which nearly the entire NOAO time allocation on the WIYN 3.5-m telescope was scheduled in a queue format. In this format, NOAO staff execute TAC-approved observing programs and investigators need not come to the mountain to do the work. Using this manner of scheduling, the observatory is conducting an experiment to maximize the scientific productivity of the 40% share of time that NOAO has on the telescope. The experiment also provides valuable experience to be applied to strategies for queue observing on the Gemini telescopes. Programs are given priority for execution primarily on the basis of TAC grade and suitability of observing conditions during a particular night. The queue experiment allows for the implementation of science programs that are difficult, if not impossible, to schedule within classical (investigator present) observing runs. Examples are synoptic programs, programs requiring less than one night to complete, and imaging projects requiring the best possible seeing that the facility can provide. Queue scheduling also easily enables the mixing of spectroscopic and imaging programs during a night because the WIYN telescope is equipped with two permanently mounted facility instruments (Hydra/MOS and CCD Imager) and has the capability of quickly switching between instrument ports. Dark-time imaging programs can, for example, be executed during the few dark hours of gray nights, with high-dispersion spectroscopy for the brighter time.

During the past two completed observing semesters, queue observing provided data for 35 of 43 TAC-approved “long” programs (observing programs requiring more than 2 hours of telescope time) and fully completed 14. There were 11 “short” programs of which 6 were completed. Unfortunately, no data were obtained for 3 short programs. The fraction of requested observations actually completed for a program largely reflects the standing (TAC grade) of the program within the queue. For these two semesters, 119 nights were allocated to the WIYN queue program. Averaged over the past four semesters 43% of this time was lost to weather and technical problems, with the latter accounting for less than 5%. The recent semester had considerable losses of time to El Niño weather. Scientific results from WIYN are beginning to appear in the refereed journals, with slightly more than half of the refereed scientific papers now in print dealing with data obtained through the NOAO queue.

Todd Boroson presented a paper at the Kona SPIE meeting analyzing the outcome of the queue experiment. The paper was based on the statistics of delivered queue data, modeling of possible outcomes had the time been classically scheduled, and an opinion poll of recipients of queue time. The queue was fulfilling expectations in delivering more data to proposals more highly ranked by the TAC than a classically scheduled model would. Highly ranked programs requiring the best seeing or photometric conditions did much better in the queue environment, and synoptic programs, such as supernova monitoring, would have been impossible in the classical mode. The data recipients felt that the staff observers running the queue were highly competent and that their data were carefully calibrated and adequate for their investigations. A preponderance of those polled, however, still held the view that they would have preferred to have taken the data themselves and taken the risks of weather with calendar night scheduling. We speculate that observers feel a stronger sense of “ownership” of the data when they are physically present at the telescope. A question to pursue is how strongly the community values efficiency of data delivery as a figure of merit for scientific productivity.

3. WIYN

WIYN continues to operate routinely and remarkably effectively, given the small size of the operational support staff (6.5 FTE, including three operators for daytime and nighttime support of visiting astronomers). The overall efficiency of WIYN was 83% in Semester 1997A and 88% in Semester 1997B, with 8-9% of observing time used by overhead. Overhead at WIYN includes time for initializing the telescope.
and subsystems, acquiring objects and setting up the guiders, tuning the optics, focusing the telescope, configuring instruments, and reading out CCDs. Some of the overhead tasks have been streamlined for more efficient operation and other improvements are planned. The time lost to hardware and software problems decreased from 8.4% for Semester 1997A to 4.4% in Semester 1997B. The time lost to technical problems is dominated by computer and software reliability issues. The effort to improve both seems to be paying off in increased efficiency.

A two-year improvement project program was launched on 1 January 1997 when special funding was obtained to increase staffing by approximately 2 FTE for the two-year period. The improvement program placed emphasis on the safety aspects of the facility. Specific action items included enhancements to the WIYN safety program and policies, upgrades to the hardware limit systems on the telescope, improvements to the access to various subsystems for maintenance, and implementation of a software system to monitor all safety systems and to provide safe shutdown modes and better alarming for the operators. Other improvements projects deal with telescope performance, reliability, and maintainability and include completion of the technical documentation to facilitate maintenance. The special funding was completely expended by the end of Fiscal Year 1998.

4. KPNO Instrumentation Improvements

FY 1998 marked the initial year of scientific use for the CCD Mosaic Imager. The KPNO/CTIO instrumentation group has produced an imager with 8096 x 8096 format that has an active imaging area of over 12 cm on a side. The imager was commissioned with 2K x 4K three-side buttable engineering grade CCDs from Loral. Twenty thinned, scientific-grade CCDs have been ordered from SITE for NOAO through a consortium purchase with Carnegie. We will then have enough CCDs for two Mosaic Imagers, and a clone is being built for CTIO. Eight of the thinned CCDs have been installed in one of the two dewars. The imager in this configuration was tested at the telescope in July, and improvements to operations have been implemented through the summer. The Mosaic Imager has been available for shared-risk observing on KPNO telescopes since June 1997, and has been scheduled for a total of 104 nights in Semester 1998B, 45 on the Mayall 4-m and 59 on the 0.9-m.

Phoenix, a high-resolution near-infrared spectrograph that operates over the spectral range 1-5 μm and uses two quadrants of an ALADDIN InSb array detector, has been commissioned and is scheduled for 56 nights of science runs on the KPNO 4-m and 2.1-m telescopes for Semester 1998B. A major failure of the replicated surface of the echelle grating from cryogenic cycling caused the cancellation of three observing blocks in the spring. A new grating blank was fabricated at NOAO, and a new replica was produced. Some minor defects remain, and a third replica is in the works. Over the summer, upgrades were made to the grating turret and selection mechanisms. The remaining outstanding problem is the image quality, which is most likely attributable to a misalignment of the camera-collimator secondary. The instrument is scheduled for Semester 1998B at KPNO. It will then be removed from service, and any remaining improvement issues, such as optical alignment, will be addressed. It will then be shipped to CTIO, for use on the Blanco 4-m, and then on Gemini South.

C. NSO OPERATIONS

1. Kitt Peak

• McMath-Pierce Main Spectrograph Control
  The computer control upgrade to the McMath-Pierce main spectrograph is now complete. A VME based computer running VXworks now controls the grating turret slew and stepper drives. The new
handpaddle allows both manual and automatic movement of the grating. In manual mode, the user can select either slew or stepper motor control, as well as three predefined speeds. As the grating is moved, the ASCII display indicates the current grating angle, wavelength, and grating order.

In the automatic mode, the user enters the desired wavelength, or grating angle and the grating order, and presses “Go.” The software will then position the grating using the appropriate combination of slew and stepper motor motions. The spectral line will appear at the photoelectric port. For quick optical setups, there is also a zero order function. In both the auto and manual mode, the user may also enter an offset angle, to shift the desired spectral feature to the photographic exit port.

Alternate methods of control have been implemented as well. A grating rock function for spatial/spectral flat fielding used during NIM observing runs has been implemented. A standard command language allows users to control the grating over a RS232 serial port. The serial/ethernet access was implemented to allow users who bring their own computers and instrumentation to directly control the spectrograph.

This project has yielded significant improvements in the flexibility and ease of use of the main spectrograph.

- **Large-Format Infrared Array and Controller**
  The McMath-Pierce facility is the world’s only large solar telescope without an entrance window, thus giving it unique access to the solar infrared spectrum beyond 2.5 μm. NSO, like NOAO, has focused its in-house instrumentation program on the 1-5 μm region. The McMath-Pierce also carries out observations in the important 12 μm region through a collaboration with NASA Goddard Space Flight Center.

NSO’s plan for 1-5 μm observations is to take full advantage of NOAO’s investment in the Aladdin array development project. With 16 times as many pixels, higher quantum efficiency, lower read-out noise, and better immunity from electronic interference, a 1K × 1K Aladdin-based camera will be superior to the current 256 × 256 camera in every respect and will enable new types of scientific observations, such as vector magnetograms of weak field concentrations.

No single instrumental improvement at NSO/KP in recent years will have a larger impact on its capabilities than this one. The large-format camera will be used for exploratory imaging and spectroscopy as well as with the Near Infrared Magnetographs.

FY 1997 and FY 1998 funds have been committed to have NOAO/ETS construct a controller for an Aladdin-based camera by mid-1999, and NSO has formally requested a science-grade 1K × 1K array from the Aladdin arrays available to NOAO.

2. Sacramento Peak

- **Adaptive Optics**
  The adaptive optics program is concentrating on implementing a low order adaptive optics system that will correct on the order of twenty Zernike modes. The hardware design is based on parallel processing using off-the-shelf DSP components. This approach should allow future expansion to a full-up adaptive optics system. The low order adaptive optics system will be capable of delivering diffraction-limited imaging in the visible during good seeing conditions and in the infrared under most seeing conditions at the VTT/SP.
A large fraction of the DSP hardware was purchased in FY 1998. The software development for the wavefront sensor part of the system has been completed. The wavefront sensor delivers the wavefront slopes at the positions of the subapertures. A reconstruction algorithm is used to derive drive signals for the actuators of the XINETICS deformable mirror from the wavefront sensor data. We are implementing a modal reconstruction scheme. A sensitivity analysis has been carried out using a bench setup. The sensitivity of a particular wavefront sensor geometry to the different Zernike modes was measured in this way and a reconstruction matrix was derived from the data. Reconstruction matrices have also been derived from purely geometrical considerations. The reconstruction algorithm (matrix multiply) and the servo control software are currently being implemented on the DSPs. At this point the software development effort is concentrated on providing a functional system that allows demonstration of the concept; at a later stage an effort will be made to provide user-friendly software.

Before taking the system to the VTT the servo loop will be closed using a test setup on an optical bench at the Evans facility.

• **Mark II Correlation Tracker**
  Development of the Mark II correlation tracker was completed in February 1997. The system has been operating on a routine basis at the Vacuum Tower Telescope at Sac Peak for well over a year and has assisted in numerous science runs where high precision tracking is essential. For example, the CT was crucial in obtaining high quality polarimetry data of high spatial resolution with the ASP and IR polarimeter instruments. The McMath-Pierce telescope and the Big Bear Solar Observatory (BBSO) are in need of correlation tracker systems. Cloning the CT system is in process. However, instead of using the specialized FFT processor that was used for the Mark II CT, we are taking advantage of the vastly increased processing power now available on high-end workstations. All digital processing can now be performed on a workstation; all software can be written in C. BBSO is providing a substantial fraction of the manpower for this joint project.

• **Fast CCD Cameras**
  NSO/SP is working towards replacing the custom built MDA detector system with state-of-the-art, large-format CCD detectors. Users have requested a variety of detectors offering different capabilities. In addition to the MDAs, the following cameras are now available at NSO/SP:

1) Two Thomson 1K x 1K cameras with 10-bit resolution and a frame rate of up to 5 frames/sec. Typically these cameras are used for high-speed imaging and frame selection.

2) A 2K x 2K 12-bit camera from Xedar Inc. in Boulder. The 2K x 2K camera achieves a high frame rate of 2 frames/sec at a low noise level (30 e). The Xedar camera is a universal camera which has been used, for example, to image the corona and for spectral imaging of large fields of view with high pixel resolution.

3) A 512 x 512 camera from Pixel Vision. The camera features a back-illuminated CCD chip from Site and offers high quantum efficiency throughout the visible spectrum, in particular at the blue end of the spectrum (CaK). The user can choose between two readout rates. At the 850 kHz rate used to achieve high frame rates, the readout noise is < 30 e. At the slow 50 KHz readout rate primarily used for low light level applications, the readout noise is < 9 e.
4) Two 1K x 1K cameras were recently ordered from Spectral Instruments. These cameras use thinned, back-illuminated CCD chips that were made available by the Air Force ISQON project.

The data storage medium is exabyte. However, DLT tape drives are now available to provide high-speed recording capabilities (5 Mb/s) and large storage capacity (35 Gb) for special applications. Two, 10 Gb hard disks are also available.

- **Dual Fabry-Perot Filter**
  A dual Fabry-Perot (FP) filter system for visible wavelengths is under development at NSO/SP. The existing narrowband (< 20 mA) Fabry-Perot filter is combined with a newly purchased 60 mA passband FP and a set of narrow (3-4 Å) blockers to provide a tunable narrow band filter with high transmission, capable of tuning at very fast speeds. In FY 1998 several observing runs with the dual FP filter were carried out at the VTT. The data were analyzed with the help of a Research Experiences for Undergraduates (REU) summer student. Spectral scans of the FeI 5576 Å and FeI 6302 Å lines were compared with the Liège atlas profiles. Compared to the UBF/FP filter combination, the dual FP system delivers excellent spectral line profiles at a highly increased throughput and therefore better spatial resolution. A time series of FeI 5576 Å velocity maps was produced from FP data. These data are currently used to study small-scale seismic events and the excitation of solar p-mode oscillations.

The software development for this project was completed in FY 1998. For FY 1999 there are plans to provide a more user-friendly optical setup and add more pre-filters to give users the capability to observe a larger set of spectral lines.

- **1998 Eclipse Expedition**
  NSO/SP, in collaboration with the High Altitude Observatory (HAO), Rhodes College, and Lindau Institute, conducted two successful infrared experiments during the 26 February 1998 eclipse in the Caribbean and Pacific Ocean. The experiments were flown on board a NCAR/RAF C130 airplane, to search for coronal spectral lines between 1-5 µm and circumsolar dust out to 10 solar radii. Preliminary analysis confirmed the prediction of the existence of the Si IX emission line at 3.9 µm, which holds great promise for future coronal magnetic field study.

- **Infrared Program**
  The NSO/SP maintains two near-IR camera systems, which were developed by outside collaborations with Michigan State University (MSU), Wyoming Infrared Observatory, and Haverford College. These cameras account for about 25% of the user time allocated at the VTT and the Evans coronagraph and are used for diffraction-limited imaging and high-precision (10-4) Stokes polarimetry for the study of various solar magnetic features.

  A new IR camera for the 1-5 µm range that will be available year-round at NSO/SP was developed in collaboration with MSU and Starfire Optical Range in Albuquerque. Currently the new camera carries an engineering-grade Rockwell International TCM2620 IR array. It was used successfully for the 1998 Eclipse expedition. A science-grade array is expected to be delivered this year. This camera will be used for general IR imaging applications and will also be integrated with the NSO/SP IR polarization analysis package for IR Stokes polarimetry.
• **Vacuum Tower Telescope (VTT) Renovation: Spectroheliograph Upgrade**
The Spectroheliograph at the Evans Solar Facility is undergoing an upgrade from film to digital. This move will greatly reduce manpower requirements for developing and digitizing film and will result in cost savings. In addition, data will be available in a more timely manner.

• **Hilltop Optical Test Facility**
The Optical Test Facility located at the Hilltop building is nearing completion. The facility consists of the remodeled hilltop coelostat, which feeds solar light onto a large optical bench. This facility allows testing of, and experimenting with, complex optical setups. Much of this instrumentation development used to be done at the telescopes. With the availability of the Optical Test Facility, valuable telescope time will be freed for science runs. The facility was cost-shared by the ISOON project and NSO/SP. Initially ISOON will be the main user of the facility.

• **Digital Library Development**
During FY 1998, substantial progress was made on the first development phase of the NSO Digital Library. Currently, the 300-disc CD-ROM jukebox holds complete sets of 41 discs of non-proprietary FTS transformed spectra, 60 discs of FTS interferograms, 44 discs of KPVT 512-channel magnetograph data, 46 discs of KPVT spectromagnetograph data, and a partial set of 13 discs of Sac Peak Evans Facility spectroheliograms for a total of about 140 GB of on-line storage.

In addition, the web-based user interface has been substantially completed, providing the ability for users to search the library catalog for a range of dates, wavelengths, and instrument categories. The availability of the interface has been announced to the user community through Solar News and the NOAO Newsletter. The web pages for the library have been created, and the suite of most recent images has been enlarged to include synoptic charts and NSO/SP coronal scans. Two new solar spectral atlases from the FTS have also been added.

A second high-resolution scanner has been obtained at NSO/Tucson to begin the migration of the collection of USNO and Mt. Wilson images from glass plates to CD. This scanner is a duplicate of the one already being used at NSO/SP to transfer the daily Evans Facility Ca K and H-Alpha spectroheliograms from film to CD.

The jukebox continues to be heavily used, with over 6,000 files downloaded by outside users in the period 1 August 1997 to 31 July 1998. In addition, 500 files have been transferred via the user interface to the Library.

D. **USGP/Science Operations (SCOPE)**
The US Gemini Program (USGP) serves as a liaison between the International Gemini Project Office (IGPO) and the US community. The Gemini Project is an international consortium to build two 8-m telescopes, one on Mauna Kea, Hawaii, and one on Cerro Pachon, Chile, in which the US currently holds a 47.6% share. The USGP was established in 1993 as a fourth division of NOAO with a status which is on a par with Kitt Peak National Observatory, Cerro Tololo Inter-American Observatory, and the National Solar Observatory.

During the construction phase of the Gemini telescopes, the major activities of the USGP have involved the procurement of the Gemini instruments assigned to the US and the discussion of scientific issues between the Gemini project and the US astronomical community. In the operations phase, beginning at the time of operations handover of the Gemini-North Telescope (currently scheduled for June 2000), the
USGP will have an additional role as the interface for US users of the telescope. The recognition of this additional role and the resources needed to carry it out led to a restructuring of NOAO, with the USGP taking on responsibility for these community interface activities in support of all the telescopes to which NOAO supplies access. In FY 1998, the USGP became an element of an enlarged division, known as Science Operations, or SCOPE. SCOPE includes more scientific staff as well as the NOAO units which provide support for the community interface activities, including Central Computing Services (of which IRAF is a part), the Tucson Photo Lab, and the Tucson Library. This report details both Gemini-specific accomplishments and those that are part of the expanded area of responsibility.

A major part of the work of the USGP during the past year has been connected with procurement of the Gemini instruments assigned to the United States. The United States is responsible for three of the initial complement of instruments, a near-IR (1-5 microns) imager, a near-IR spectrograph, and a mid-IR (8-30 microns) imager. The NSF assigned the near-IR imager to the University of Hawaii; the USGP is responsible for the procurements of the other two instruments. The near-IR spectrograph was assigned to the NOAO instrumentation group through a competitive selection in FY 1995. The mid-IR imager was assigned to the University of Florida through a competitive selection in FY 1998. At the request of the IGPO, the USGP has taken on the management of these instruments as the Gemini IR Instrument Program. This approach allows one group, the USGP, to look out for interface issues, to identify areas of commonality among instruments, and to help solve problems in areas of budget, schedule, and risk.

During FY 1998, the USGP completed the selection of a group to build the Gemini mid-IR imager through a process that will serve in some ways as a model for future Gemini instrument procurement activities. Through a competitive selection during the previous year, two groups were awarded funding to conduct conceptual design studies. In addition, two other groups agreed to perform studies at their own expense. The results of these four studies were presented to a panel of technical and scientific experts, and the comments of these experts were incorporated into the RFP for a second competitive selection of a supplier to produce a final design and fabricate the instrument. An outside committee evaluated proposals in response to this RFP, and the University of Florida was selected to produce a detailed design and build the instrument. Because the Gemini international agreement specifies that Gemini funding is limited to an amount equivalent to the direct costs only (no overhead) for instruments built by the partner countries, additional funding had to be secured from the National Science Foundation to cover the fraction (approximately 50%) of the overhead costs that the University of Florida could not contribute. This work is now well under way, and a preliminary design review was held in mid-September 1998.

After the selection of a supplier for each instrument is made, the USGP remains responsible to the Gemini Project for seeing through the successful design, fabrication, and delivery of each US-allocated instrument. This activity includes day-to-day monitoring of progress by each of the instrument suppliers, identifying concerns that have implications for cost, schedule, or risk, and helping the groups work out solutions to these concerns. During FY 1998, USGP personnel worked with the University of Hawaii near-IR imager group as well as groups at NOAO involved in the near-IR spectrograph, the near-IR arrays, and the near-IR array controllers.

While instruments from the initial Gemini complement were assigned to one of the partner countries before groups were selected to build them, the procedure has changed for the ongoing instrument program. The Committee of Gemini Offices (CGO), comprising the national project scientists, national project managers, and Gemini personnel involved in the scientific instruments and operations, meets semi-annually to discuss instrument and operations issues. In the part of these meetings known as the instrument forum, the CGO formulates the ongoing instrumentation plan and recommends groups to carry out design studies and build instruments. The proposals to undertake this work are solicited from the national project offices in each of the Gemini partner countries. The current instrumentation plan
spans approximately ten years, and the elements identified for early work include laser-guide-star adaptive optics, polarization modulators for the acquisition and guide unit, a near-IR coronagraph/imager, and development studies for a near-IR multi-object spectrograph. For each of these instrument activities, the USGP has solicited expressions of interest and/or proposals from the US community.

In the March 1998 instrument forum meeting, the committee evaluated proposals for the polarization modulators and for the adaptive optics system. There was no interest in the polarization modulator work from US groups, and the conceptual design of this system was assigned to a UK group. For the adaptive optics work, the USGP submitted a proposal for a development process by which any group interested in participating in the design could present their case in an open forum for evaluation by an unbiased committee of experts. The forum chose to recommend a process that is a hybrid of the US proposal and one put forward by the IGPO in which a small IGPO group would lead the work. This work has yet to begin, but an open forum for discussion of the best way forward is scheduled for March 1999.

The September 1998 instrument forum meeting was the first one attended by representatives of Australia, the newest Gemini partner. The instrument work to be allocated included the conceptual design for a Near-IR coronagraph/imager and development studies for a Near-IR multi-object spectrograph. When expressions of interest were solicited by the USGP for the coronagraph/imager, five US groups indicated that they would like to propose. Because each instrument forum member advocates the proposal that he/she has brought to the forum, a pre-selection to identify the US proposal was necessary. The USGP organized this by inviting the five groups to attend an open, informal meeting to discuss their perspectives about the coronagraph/imager design in front of an unbiased committee of experts. This committee recommended that a single group, led by Douglas Toomey (Mauna Kea Infrared), be asked to write the US proposal. Groups not selected were urged to undertake unfunded design studies in order that they might compete effectively in the next stage, a competitive selection for a final design, and in the fabrication of the instrument. At the instrument forum meeting, funding for the US proposal was recommended. This recommendation must now be approved by the Gemini Board.

The other instrumentation work, development studies for a near-IR spectrograph, was handled differently. The intent of these studies is to mitigate risk in areas of significant technological uncertainty. Because a number of different areas and approaches were expected, the USGP submitted both of the proposals that it received to the instrument forum. One of these, a study of micro-mirror array performance and utility was recommended for funding at a reduced level. This work will be undertaken by a collaboration that includes NOAO, STScI, and GSFC.

The other CGO activity is known as the operations forum, and in this meeting the members have begun to explore issues such as the timing for the first call for Gemini observing proposals, the requirements and specifications for a Gemini scientific archive, and procedures for handling outreach and public relations within the Gemini partner community. Another area of concern is how the national Gemini offices will support information requests from members of their communities. Operations forum discussions have explored how Web-based information will be distributed and whether a software system known as an electronic help-desk could facilitate a distributed approach to providing such support.

The USGP is responsible for keeping the community informed about Gemini's progress and fostering community support for Gemini. Displays are regularly presented at AAS meetings, and USGP staff contribute status information to both NOAO and Gemini newsletters. In addition, the USGP provides routine information about Gemini activities and milestones of interest to US astronomers and the public through electronic and printed media.
Another USGP responsibility is the monitoring of technical developments within the project. The US Gemini Project Scientist serves on the Gemini Science Committee (GSC) and represents there the views of the US scientific community. In addition to the GSC and project scientist team teleconferences, formal input is contributed through participation in reviews and working group meetings organized by the project. The USGP also solicits membership for US participants in these reviews and meetings and organizes the US participation in the GSC.

In a less formal sense, the USGP personnel interact frequently and directly with the Gemini Project to provide scientific and technical feedback, to identify scientific performance issues and to help define technical solutions to meet the science requirements, to evaluate implementation plans, and to participate in source selection for critical systems and components.

The USGP has participated intensively in the development of a plan for the evolution of responsibilities in the operations phase of Gemini. The international Gemini Office will continue to depend on the national Gemini offices for a great deal of assistance in interacting with the user communities of the partner countries. The national Gemini offices will solicit proposals, perform technical evaluations, run national time allocation and users’ committees, and will provide assistance to astronomers in writing Gemini proposals and reducing Gemini data. As a result of these considerations, the process of turning the USGP into an organization with the capability to carry out these activities has begun, as mentioned at the start of this report. As SCOPE, this division has responsibility for:

- Providing information to the US astronomical community about all the capabilities available through NOAO and how they can most effectively be used;
- Unifying and coordinating the process by which telescope time proposals are submitted, processed, and reviewed;
- Organizing a mechanism by which astronomers can obtain assistance in preparing observing proposals, preparing for observing runs, and reducing their data. This may include, in the case of Gemini and the independent observatories that are supplying national access time in exchange for NSF funding for their instruments, identifying personnel who will become “instrument specialists” for these telescopes;
- Providing software, where appropriate, for reduction of data for all instruments to which NOAO provides access;
- Developing concepts for, and implementing, an archive so that the community can make the most effective use of the data that come from all facilities to which NOAO provides access;
- Exploring concepts and implementations for alternative modes of operation such as remote observing and queue scheduling that may enable scientific investigations that are impractical or difficult given the constraints of classical modes;
- Developing and implementing a program of scientific outreach, through which a dialog with the astronomical community about NOAO’s mission can take place, including both the presentation of that mission in order to foster community support and the solicitation of input from the community to make NOAO more responsive to the community needs.

FY 1998 accomplishments in these areas included:
1. As a follow on to the workshop that was held last year identifying the ability to undertake surveys as an essential capability needed for effective use of very large telescopes, a program aimed at enabling such surveys has been initiated. At the suggestion of the NOAO nighttime users' committee, a working group was convened to recommend a specific implementation process for the survey program that would ensure its scientific effectiveness. A detailed plan based on the recommendation of the working group is currently undergoing review. It is expected that this program will begin in semester 1999B, and that a call for proposals will be issued at the end of this year.

2. One of the pieces of infrastructure that is required to make such a survey capability useful is a data archive. A plan to begin an NOAO nighttime data archive is now nearing completion. The initial data in the archive will be limited to that from the new KPNO CCD Mosaic Imager, but it will be implemented in a manner that will be extensible to include other instruments in the future. Data will be reduced in Tucson using a software pipeline under development and the storage and community interface will be contracted out to Space Telescope Science Institute.

3. Work continued in FY 1998 on the evolution of the telescope proposal process to support Gemini and other facilities in a uniform and consistent way. In recognition of the common problem faced by all the Gemini partners, a workshop was held to discuss various approaches to proposal forms, databases, and other parts of the proposal process. Participants included representatives from SCOPE, the Canadian Gemini Project Office (CGPO), IGPO, as well as STScI, the Joint Astronomy Centre, the CFHT, and the Anglo-Australian Observatory. One of the outcomes of this workshop was an agreement among SCOPE, CGPO, and STScI to develop a proposal system that would maintain the advantages of the current NOAO form (shared by STScI) but would feed easily into the Gemini database.

4. The TAC process also continues to evolve toward a consistent approach that supports a science-based view of capabilities available to the community. For the 1998B semester, the proposals for time on all KPNO telescopes were reviewed by three panels, galactic, extragalactic, and solar system. A joint TAC, convened subsequent to the panel meetings, dealt with mechanisms for combining the recommendations from the panels into rank-ordered lists for each telescope. This procedure will be further developed next year, when the CTIO time allocation process merges with this one. Initially, requests for northern and southern telescope time will be reviewed by different panels, but single proposals for time north and south will be permitted. Representatives of all panels will take part in the joint TAC meeting. It is expected that this discipline-based approach will be extended to the nationally available time on the Hobby-Eberly Telescope, the MMT, and the Gemini Telescopes over the next several years.

E. NOAO Instrumentation

The mission of the Instrument Projects Group (IPG) is to develop and produce major instruments for the NOAO nighttime telescopes, including KPNO, CTIO, and Gemini. The NOAO scientific staff conceives, directs, prioritizes, and evaluates the instrumentation projects; the engineering managers are responsible for meeting schedule, budget, and performance requirements. NOAO astronomers initiate new instrument projects in response to user requests, scientific staff interests, advances in technology, and announcements of opportunity from the International Gemini Project.

Managing the instrumentation resources efficiently and in a manner satisfactory to both sites is crucial to the success of our program. The Instrument Projects Advisory Committee (IPAC) provides scientific prioritization to the IPG. Its current members are Taft Armandroff (NOAO-Opt. Instr.), Todd Boroson
(USGP), Dave De Young (KPNO), Jay Elias (GNIRS Project), Richard Green (NOAO-Chair), Tom Ingerson (CTIO), and Alistair Walker (CTIO). IPAC meets with the instrumentation engineering managers about once a month to review priorities, schedules, and budgets. They develop the scientific content of the long-range plan, on the basis of input from the users through the Users’ Committee and personal contact, from the WIYN and SOAR partners, and from the Gemini advisory structure through the USGP. Every instrument under development has an instrument scientist from the NOAO scientific staff. We believe that this arrangement is essential for successful development: each instrument must have an intellectual champion to see that the project meets its scientific performance goals. IPAC provides a venue where the interests of each site are fairly represented.

Concurrent with the establishment of IPAC, we put into place a revised system of project management. It placed greater emphasis on initial design and planning and on overall accountability and resource tracking. Neil Gaughan is the engineering projects manager. The IPG reports to him, and he reports to Larry Daggert, the manager of ETS. IPAC works with Neil Gaughan and Larry Daggert to produce a detailed plan for the annual allocation of technical resources which is recommended to the Director and the NSF. It also organizes and participates in non-advocate design reviews for major projects. A system of review gates controls the rate at which resources are made available to a project, subject to the successful completion of the previous review stage.

During FY 1998, our ongoing projects advanced, as described below.

1. **CCD Mosaic Imager**

Major progress was made in FY 1998 on the upgrading and cloning of the CCD Mosaic Imager. IPG has produced an imager with 8192 x 8192 format that has an active imaging area of over 12-cm on a side. It has a large filter transport mechanism holding 14 six-inch filters and a pneumatically controlled shutter mechanism that gives 1% timing accuracy in one-second exposures. The Mosaic was upgraded over the summer to employ thinned, scientific grade CCDs. The CCD controller is a multiplexed quadruple version of the ARCON, developed and produced at CTIO. The second Mosaic is scheduled for completion in FY 1999, with deployment at CTIO in the first half of the calendar year. The assembly of Mosaic II mechanically will be essentially complete by the end of FY 1998; deployment will depend on the delivery of the remaining SITe CCDs and progress in retrofitting the Blanco Telescope prime focus.

2. **Phoenix**

Phoenix is a high-resolution near-infrared spectrograph operating from 1-5 μm using two quadrants of an ALADDIN InSb array detector. The instrument received a number of upgrades to mechanisms during the year, as well as the replacement of the echelle grating, as described above. After final resolution of the optical performance starting next January, the instrument will be shipped and re-commissioned at CTIO.

3. **Hydra for CTIO**

A new version of the Hydra multi-fiber positioner is being constructed for the CTIO 4-m telescope. In the area of wide-field multi-fiber spectroscopy, the existing 4-m telescopes complement the capabilities of the Gemini telescopes. The present multi-fiber instrument at CTIO is Argus, which was designed almost a decade ago. It is capable of observing 24 objects at a time, which puts it at a factor of four disadvantages, compared with more modern instruments such as KPNO’s Hydra. The new multi-fiber system is being built in Tucson and is based largely on the design of Hydra as it was converted from use at the Mayall to use at the WIYN. New motor controllers, a new gripper, and new fiber cables are being produced for the system for CTIO, along with a new wide-field corrector with atmospheric dispersion.
compensating prisms. This instrument will be located at the f/8 Ritchey-Chretien focus and will take advantage of the excellent image quality by using fibers of smaller on-sky diameter than those of Argus. Delivery and first commissioning activities are planned for October 1998. The project remains on schedule according to its initial plan. The staff mourns the untimely death of Lee Groves, the creator of the fiber placement software system.

4. SQIID Upgrade

A high priority for the users, as expressed through the Users' Committee, is wide-field near-IR imaging. The first realization of that capability will be in the upgrade of SQIID, the four-color near-IR imager. The 256 x 256 PtSi arrays will be upgraded to 512 square InSb arrays with a customized NOAO/Gemini Controller. That instrument should be available for commissioning observations on Kitt Peak in spring semester 1999, now that an adequate number of InSb arrays is available. The primary effort on this project during FY 1998 was mechanical design work and electronics design of new multiplexing circuits to allow the incorporation of the new, larger arrays. Delays with respect to the previous schedule were induced by the extra efforts required on Phoenix and the Gemini IR projects.

5. Gemini IR Array Controllers

The first instrument required for commissioning the first Gemini telescope is the Near-Infrared Imager (NIRI) under development at the University of Hawaii. NOAO has produced for NIRI a powerful array controller based on the WILDFIRE heritage that relies on the digital signal processor produced by Datacube. That system passed its acceptance review and has been delivered to Hawaii for integration into the imager. The array controller has very low noise and meets NIRI's speed requirements. The design will serve as the basis for controlling the arrays in the other near-infrared instruments that will be used on Gemini, some of which will be provided by and shared with NOAO, such as COB and Phoenix. NOAO has produced three copies of the controller, one for the IR Spectrograph, one for a laboratory system, and one for potential use in a spectrograph clone.

6. Gemini Near-IR Spectrograph

The major instrument under production for Gemini is the Near-IR Spectrograph (GNIRS). This project is the largest IR instrument ever undertaken by NOAO. The dewar will be 2 meters in length, and the instrument weighs some 2000 kg, including electronics. It will provide long-slit capabilities with a range of dispersions through selectable gratings, covering the wavelength region from 0.9 μm to 5.5 μm at two pixel scales by means of four interchangeable cameras, which feed a single 1024 square ALADDIN-type InSb detector. The Gemini IRS project successfully passed its Critical Design Review in November 1997. A recent internal review has revealed that the effort required to complete the instrument to specification would considerably exceed the estimates presented at CDR. The likely impact is that NOAO will devote more of its resources to supporting the largest community-accessible telescope, Gemini, and less to upgrading the instrument suite on the existing 4-m telescopes, at least in the near term.

7. High-Efficiency Spectrograph and Other O/UV Projects

Long-term studies are currently underway to define a new-generation moderate-resolution spectrograph for the 4-m telescopes. Scientific performance tradeoffs are being investigated to identify the most effective combination of field of view, spectral dispersion, and wavelength coverage. A key goal is to use the new generation of large-format CCDs with smaller slits and adequate pixel sampling, in order to exploit the expected improvement in delivered image quality. In addition, the use of holographic volume phase
gratings, coupled with the highest performance anti-reflection coatings on all optical surfaces, should allow a significant increase in throughput. Conceptual optical designs are under development.

In FY 1999, we will complete design and begin construction of a tip/tilt CCD imager for WIYN, deploy a CCD MiniMosaic for WIYN resulting in a 4K x 4K format, and complete the integration of CCDs and CCD Controllers for Gemini’s GMOS instrument.
V. MAJOR PROJECTS

A. GONG

The Global Oscillation Network Group (GONG) is an international, community-based project designed to conduct a detailed study of the internal structure and dynamics of the closest star by measuring resonating waves that penetrate throughout the solar interior. In order to overcome the limitations of observations imposed by the day-night cycle at a single observatory, GONG is operating a six-station network of extremely sensitive and stable solar velocity mappers located around the Earth obtaining nearly continuous observations of the “five-minute” pressure oscillations. GONG is also operating a distributed data reduction and analysis system to support the coordinated analysis of these data. GONG data are available to any qualified investigator whose proposal has been accepted; however, active membership in a GONG Scientific Team allows early access to the data and the collaborative scientific analysis that the Teams have already initiated.

A Scientific Advisory Committee—consisting of P. Gilman (High Altitude Observatory), R. Noyes (Harvard-Smithsonian Center for Astrophysics), A. Title (Lockheed Martin Solar and Astrophysics Laboratory), J. Toomre (University of Colorado/Chair), and R. Ulrich (University of California, Los Angeles)—continues to provide overall scientific guidance to the project. In addition, a Data Management and Analysis Center Users’ Committee—consisting of Philip Stark (University of California, Berkeley/Chair), Rachel Howe (Queen Mary and Westfield College), Sylvain Korzennik (Harvard-Smithsonian Center for Astrophysics), Jesper Schou (Stanford University), and Steve Tomczyk (High Altitude Observatory)—provides important community input to this critical part of the project.

The GONG stations are hosted by, and operate in close collaboration with, major international solar facilities: Big Bear Solar Observatory in California, the High Altitude Observatory’s site on Mauna Loa in Hawaii, the Learmonth Solar Observatory in Western Australia, the Udaipur Solar Observatory in India, the Observatorio del Teide on Tenerife in the Canary Islands, and the Cerro Tololo Inter-American Observatory in Chile.

The project’s Tucson-based operations staff maintains daily contact with the automatically operating site instruments, via modem or internet, checking the current state of the instruments and reviewing any informational messages generated by the real-time system. Each of the network instruments generates a 200 parameter database which is transmitted to the Tucson station once a day to facilitate the review and analysis of the functioning of the remote instruments, including fault diagnosis and the detection of performance anomalies and long-term trends. When problems occur or rapid attention is required, the network operations “on call” duty responder can be readily accessed via phone, fax, or e-mail. The instruments are also monitored locally by scientists and technicians at the host observatories.

The technical performance and reliability of the network continue to be excellent. The data duty cycle is currently about 87% and the daily sidelobe artifacts are virtually invisible. Of all the possible images that could be obtained at the individual sites, less than 2% have been lost to equipment down-time, primarily scheduled maintenance, and many of these gaps were filled by images taken at adjacent sites.

The Data Management and Analysis Center (DMAC) has successfully completed nearly three years of operations, during which time it has kept adequate pace with the incoming field data from the six sites. These data are reduced to 36-day time series (a “GONG month”) of oscillation-mode coefficients and transformed to obtain the frequency spectrum for each mode. The project embarked on a reprocessing campaign to produce a more homogeneous data set. This effort has been operating in parallel with the processing of newly acquired data, and will be completed early FY 1999. The data from these and other
processing steps are archived in the Data Storage and Distribution System, which is also responsible for
the distribution of archived scientific data products to the community (requests are typically received by
email and via GONG's web site, and most data distributions are satisfied by internet transfers). In addition,
the DMAC staff also provides support to the in-house science analysis team and community
contributors in an ongoing effort to improve understanding of the data and enhance the quality of the data
reduction processes. Several such enhancements have been developed and incorporated into the current
data pipeline over the past three years.

With the continuation and data acquisition for a full eleven-year solar cycle established, the instrument
group has turned its attention to remedying the deficiencies of the initial camera system. The camera
development and upgrade (a.k.a. GONG+) includes the replacement of the current cameras with high-
resolution detectors and the integration of high-speed electronics into the existing Doppler imager optical
system. The GONG+ system should provide far superior data, with a significantly improved signal to
noise ratio, square pixels with uniform spatial resolution (2.5 arcsec pixel resolution), the absence of
spatial aliasing (the new detector will provide spatial resolution comparable with the optical system
resolution), and a factor of 16 improved areal resolution (1024^2 CCD). GONG+ will also provide
continuous magnetograms: the magnetograms will be summed for 5 minutes to increase sensitivity,
reduce data volume, and reduce the signal to noise. The GONG+ systems should be deployed by mid-
FY 2000.

The GONG+ system, by adding a factor of sixteen areal resolution and continuous line-of-sight magnetograms,
presents a formidable task for the current DMAC data reduction pipeline. Initially the data will be
reduced to roughly the same resolution as currently used, to fit within the existing DMAC capabilities. In
order to address the GONG+ processing limitation, the project will propose for another phase, GONG++,
implementing a high-performance computing capability.

The GONG 1998 Annual Meeting and the 6th SoHO Workshop were hosted by the CFA and held jointly
in Boston, 1-4 June. The workshop focused on the results from the continued GONG operations and the
helioseismic experiments aboard SoHO (GOLF, MDI/SOI, and VIRGO). Results from other groundbased
multi-site projects, TON, MWO-CRAO, BISON, and IRIS, were also included. The meeting was well
attended, with about 170 participants, included a continuous three-day poster session which featured over
160 works in progress, and provided the presentation and discussion of scientific analyses of data from
recent experiments, new directions and ideas in helioseismology, and results and perspectives for seismic
studies of other Sun-like stars. The Annual Meeting provided an opportunity for project-specific support
groups to meet as well: the project’s Scientific Advisory Committee, the DMAC User’s Committee, and
representatives from five sites were in attendance, providing a rare opportunity to discuss site issues.

The project had the pleasure of hosting extended scientific visits for Rafael Garcia, Irene Gonzales, and
J. Javaraiah during the year.

B. RISE/PSPT

The Italian PSPT telescope was deployed at the Osservatorio Astronomico di Roma and now generates
solar precision photometric data on a daily basis. A second PSPT began operation in early 1998 from
Mauna Loa and is jointly operated by the National Solar Observatory and the High Altitude Observatory.
These instruments will allow, for the first time, full-disk photometric measurements of the differential
surface brightness of the Sun with an accuracy comparable to the precision of absolute bolometric meas-
urements from space.
The PSPT operations were descoped from the original 1992 plan, and budget constraints have made it necessary to depend heavily on commercial vendors and partnerships with other institutions. Nevertheless, with the proposed configuration, daily measurements of solar photometric variability are being achieved. Occasional higher cadence observations will be possible (for example, to support space experiments or brief periods of exceptional solar activity), depending on the availability of support from partner institutions. In this configuration a capability of satisfying the data needs of up to 10 research groups is expected, but much of the higher level data processing beyond the lowest level instrument calibration will be the responsibility of scientific collaborators.

To date, partnerships have been established with two other institutions, the Osservatorio Astronomico di Roma, which operates the Rome facility, and the NCAR High Altitude Observatory (HAO), which has agreed to collaboratively provide a RISE data distribution center (primarily from HAO). Spanish astronomers at the IAC have also expressed an interest in a partnership to operate a PSPT on Tenerife.

C. SOLIS

SOLIS (Synoptic Optical Long-term Investigations of the Sun) is a project to make optical measurements of processes on the Sun, the study of which requires well-calibrated, sustained observations over a long time period. The project was conceived in 1995, proposed to NSF in January 1996 as part of a “Renewing NOAO” proposal, and received partial funding in January 1998. The design and construction phases will require three years and the 25-year operational phase will start during FY 2001. The project was descoped at the request of the NSF when funding fell short of the request. A Science Advisory Group provides expert advice from a wide range of the user community. The High Altitude Observatory and NASA are active partners in SOLIS. The project is also sharing results and experience with other NSO projects including RISE/PSPT, GONG, and ISOON.

After descoping, SOLIS consists of three instruments that will be temporarily mounted on the top of the existing Kitt Peak Vacuum Telescope, pending availability of a superior, affordable site. The three full-disk instruments on a common mount are as follows: (1) A Vector Spectromagnetograph (VSM) to measure the strength and direction of the photospheric magnetic field, the line-of-sight component of the chromospheric magnetic field, and the intensity of the helium chromosphere. (2) A Full Disk Patrol (FDP) that provides digital, one arcsec images of the full disk showing the intensity and line-of-sight velocity in a number of spectrum lines at high cadence. (3) An Integrated Sunlight Spectrometer (ISS) furnishes sun-as-a-star spectra at both high and medium spectral resolutions with emphasis on high photometric precision and stability. A major part of SOLIS is data processing, distribution, and archiving.

The SOLIS project formally started in February 1998. The first seven months of the project have been devoted to the following major activities: (1) Formation of science and technical teams to focus on specific aspects of SOLIS. This required allocation of existing NSO and NOAO personnel and resources, including five new hires. The process took longer than anticipated because of the tight job market and competition from other high priority projects in NSO and NOAO. (2) Development of improved specifications and requirements. This has been done mainly using web-based tools. (3) Design of optical, mechanical and software aspects of SOLIS. (4) Procurement of long-lead time or technically risky components. The primary example is the custom CCD camera for the VSM. (5) Laboratory tests of certain technical issues. Examples include various computer hardware components; fiber optic feeding of the ISS; grating efficiency; VSM secondary mirror cooling methods; and prototyping the guider for the VSM. (6) A study of options for accommodation of SOLIS on top of the Kitt Peak Vacuum Telescope. (7) Preparation of status reports to the NSO staff, the SOLIS Scientific Advisory Group, NOAO, and NSF.
During FY 1999, the major events for SOLIS will be continued testing and prototyping, and a design review followed by a transition from design to construction. Major purchases will include the CCD cameras for all of the instruments, the majority of the ISS (from a commercial vendor), and computing hardware. We expect to learn if a proposal by the High Altitude Observatory to NSF/ATM to construct two additional VSMs will be funded. The SOLIS-funded staff will reach 6.5 FTE with additions from the NSO and ETS bases augmenting this roster. Planning for cross calibration between the new SOLIS instruments and the old synoptic equipment (to be retired) will be initiated during FY 1999. Scientific observing plans with the NASA HESSI mission (to be launched in late 2000) will be started.

D. Advanced Solar Telescope Studies

Large solar telescopes are needed to address a number of important science issues. Among the desired capabilities are: (1) high angular resolution needed to resolve the scales at which most of the action takes place in solar magneto-hydrodynamics; (2) access to the infrared part of the solar spectrum, which is required to extend the range of physical conditions over which the solar atmosphere is studied; (3) accurate polarization observations needed to measure solar magnetic fields; (4) high sensitivities, essential to study variations in these and other solar conditions; and (5) low scattered light to observe magnetic fields and small-scale structures in sunspots and in the solar corona. CLEAR is one concept which attempts to combine these qualities in one telescope.

This year saw progress in the development of the CLEAR concept. An interim technical and budgetary feasibility study of the CLEAR project has been completed. A major part of it was published (SPIE Proceedings 3352, p. 572, p. 588, 1998). Since then the M3 Corp. has done a phase A study of the telescope enclosure and of the "coudé cage." The studies have so far shown no "showstoppers." The studies have focused on a 400 cm aperture, air-filled telescope with off-axis, low-scattered-light optics covering the entire 0.3-30 µm wavelength region. It has a number of foci, some direct or folded f/30 Gregorian foci, others coudé foci. The coudé area contains a large rotating instrument platform to allow removal of the image rotation. The technical part of the study is expected to be completed in 1998. The final report contains, in addition to the technical description of CLEAR, a cost accounting as a function of telescope diameter (down to 200 cm) and degree of scattered light control. Scattered light control at the coronagraphic level adds less than 10% to the cost.

Using solar scintillometry as a proxy measurement for site seeing assessment, we confirmed earlier observations by Evershed and Leighton, who demonstrated the superiority of lake sites for high-resolution solar observations. Continuous observations at mountain locations (Mauna Loa, Kitt Peak, Sac Peak, and La Palma) show strong effects of the daytime build-up of boundary layer seeing, limiting good seeing most of the time to early morning. Big Bear, and four other lake sites tested, show on the other hand that the boundary layer seeing is absent all day, resulting in all-day-long good seeing. As a result, their median seeing values are superior to that of mountain sites, approximating the best of nighttime sites. Future site measurements will focus on improving the database, testing the effects of lake size, depth and wind direction, and testing the effects of water vapor and measurement of sky brightness. In FY 1999, we will develop a Solar Dual Image Motion Monitor (S-DIMM) with which we will check the scintillometer results with more direct optical seeing observations. In addition, we will start exploiting a technique to measure height variation of the atmospheric seeing disturbances, a technique which relies on the observations of the full solar disk shadow band patterns. It results in estimates of the Fried parameter, isoplanatic patch size, and coherence time of the atmospheric seeing.
Adaptive optics are an essential component of any Advanced Solar Telescope. The NSO adaptive optics program being developed at the NSO/SP Vacuum Tower Telescope is a critical component of the AST program. Its progress and plans are described elsewhere in this report.

E. SOAR

The SOAR project has as its goal the construction of a 4-m class telescope in Chile. Partners in this project, in addition to NOAO, are the Conselho Nacional de Pesquisas Científicas e Tecnológicas (CNPq), representing the astronomical communities of four states in Brazil, the University of North Carolina at Chapel Hill (UNC-CH), and Michigan State University (MSU).

A groundbreaking ceremony was held on Cerro Pachon in April 1998. The concept design phase, which defined the performance requirements for the SOAR Telescope, developed the concept for the telescope and associated support facilities that will meet these requirements, and estimated the cost of the fabrication and installation phases of the SOAR project. The results of the concept design phase were subjected to external review in June 1998. On the basis of that review, the partners agreed to proceed with construction. The project team for SOAR is based in Tucson. The project manager is Tom Sebring, who was project manager for the recently dedicated Hobby-Eberly Telescope, and the project scientist is Gerald Cecil from the University of North Carolina.

The primary science requirement for the telescope is superb image quality: the goal is for the telescope to degrade the image quality delivered by the atmosphere by no more than 0.18 arcsec FWHM. The primary mirror will be a thin meniscus, which will have active support and thermal control systems. The mount will be an alt-azimuth configuration with two Nasmyth ports for mounting instruments. Scattered light will be minimized through careful attention to baffling, polishing, etc. The telescope will be located on Cerro Pachon, close to the site selected for the Gemini telescope. The instrumentation package for the telescope is currently being defined.

An English-language Web page for SOAR is being maintained at MSU and can be accessed through the NOAO home page.
VI. CENTRAL COMPUTER SERVICES

A. Tucson

The downtown Tucson computing facilities continue to evolve as older systems are replaced by newer, more cost-effective and easier-to-maintain systems. In particular, three new machines (built using PC hardware and running the FreeBSD operating system) were brought into service during FY 1998 to handle the NOAO-Tucson Web site, to receive and process KPNO telescope proposals, and to provide email and FTP service. In addition, the Sun serving as the home base for the IRAF project was upgraded and the desktop workstations of the IRAF group members were upgraded.

Several older disk drives on various CCS systems failed during the year and were replaced by more reliable, and also larger, disks. Similarly, newer, more capable printers replaced older laser printers.

The proliferation of desktop workstations, PCs, and X-terminals to scientists’ and engineers’ offices has slowed as saturation is approached; however, many desktop systems were upgraded to faster systems over the course of the year. The network infrastructure in the downtown Tucson office building was upgraded with the goal of providing Fast Ethernet connections to every scientist’s desktop workstation (backed up by a Gigabit Ethernet backbone) by the beginning of 1999.

B. Kitt Peak

During FY 1998, the NOAO Mosaic Imager became a workhorse instrument. This instrument features a Sun SPARCstation-10 to capture the data from the Arcon imagers and a Sun Ultra-2/2200 to process, archive, and display the data. These computers move with the Mosaic instrument between the 4-m and 0.9-m telescopes.

Also during FY 1998, the system used to capture telescope data and store it on tape (Save the Bits) was upgraded to a much more capable Sun system. Mosaic data are now being captured by Save the Bits.

Finally, a new Sun Ultra-60/2360 was installed at the 4-m to provide a fast and capable data reduction and analysis system to 4-m observers.

C. Mountain Programming Group

During FY 1998, we provided an uninterruptible power supply for each programmer’s workstation and two additional systems to keep the lab machines running. Two laptops, for home and travel work, were acquired. Two Linux machines were purchased, as well as a new PC for administrative and software development work.

D. CTIO - Cerro Tololo

The CTIO mountain network consists of the data acquisition computers located in the various domes, one or more of which are used by all visiting observers, and a number of ancillary machines employed by support staff.

During FY 1998 a Sun Ultra-2/2200 with 512MB of memory and more than 40GB of disk storage was installed at the 4-m telescope. Such a powerful machine is needed to efficiently handle the large volume of data generated by the BTC mosaic imager in use now and the NOAO 8K x 8K mosaic imager which will come into service in early 1999.
CTIO's current optical (Arcon) and IR (Wildfire) detector controllers use S-Bus host interface boards. Sun Microsystems has switched from the S-Bus to the PCI bus for their new generation of workstations. End of FY 1998 funds are therefore being used to upgrade the CPU and memory of the existing S-Bus based data acquisition machines. An adequate stock of spares will be purchased in order to keep these machines running for the remaining useful life (envisioned to be five years) of these detector systems. Future expansion will be allowed for by offloading much of the data-handling task to more capable (and freely upgradeable) companion machines. Two Sun Ultra-10/300's each with 128Mb of memory and more than 20Gb of disk storage have been purchased to serve this role at the 1.5-m and 0.9-m telescopes. They also replace ancient and ailing VME bus based machines.

End of FY 1998 funds have also been allocated for the purchase of switched Ethernet hardware, similar to that installed in La Serena during FY 1997, which will replace the existing conventional Ethernet backbone on Cerro Tololo.

E. CTIO - La Serena

The computer facilities in the La Serena offices serve the needs of diverse groups: visiting astronomers; the resident scientific staff; the engineers of the CTIO ETS; and the secretarial and administrative staff.

During FY 1998 three new desktop workstations were purchased and a number of older workstations were upgraded in order to accommodate a net increase in the size of the CTIO staff. As an experiment the new computers are high-end Pentium-II PCs, configured as Linux workstations, rather than the traditional Sun machines. CTIO has also purchased a multi user license for the IDL image analysis package needed for reduction of data from the 4-m f/14 tip-tilt system and also by some of the incoming staff members for their own scientific programs. The La Serena network infrastructure was completely replaced by installing switched Ethernet hardware that supports both fast and slow sub-nets.

End of FY funds have been allocated to purchase three Ultra-10/300 workstations. One of these will serve as a public machine specifically targeted at the analysis of data generated by BTC and the NOAO mosaic imager. The other two replace older central servers that double as general-purpose public machines. Hardware is also being purchased to implement a centralized disk back-up system that will protect La Serena users against loss of data caused by disk failures.

F. CTIO - Communications

The installation of a fiber optic backbone running the length of the country, which will soon have a direct connection to the US Internet, is bringing about a revolution in the Chilean telecommunications business. CTIO is negotiating membership in REUNA2, the Chilean University Internet consortium, which should lead to a significant increase in bandwidth of CTIO's connection to the US Internet. In parallel with this various options for increasing the bandwidth of the link between La Serena, Cerro Tololo, and eventually Cerro Pachon are being investigated in preparation for the start of Gemini and SOAR operations.

G. NSO - Sunspot

1. Upgraded six older Sun workstations to Sun Ultra five workstations.

   We compared the Sun Ultra 5 with a similar Pentium II 233MHz system running Solaris 2.6. The difference in cost of the Ultra 5 and the Pentium II system was ~ $300. The added cost for the Sun Ultra 5 was made up by faster floating point calculations over the Pentium II, faster IO to the IDE
disk, and compatibility of binaries with all our Sun workstations. The older workstations were moved
to our public workstation area for visitor summer student use.

2. Upgraded/purchased two new Ultra SPARC systems to run CCD cameras at the VTT.

3. Provided an analysis of our network and an upgrade path to a gigabit Ethernet backbone to NSO/SP
management. We will purchase the hardware in two to three phases. The first phase of equipment
will be purchased at the end of FY 1998.

H. NSO - Tucson

1. Completed the first phase of the NSO Digital Library development. The entire KPVT and McMath-
Pierce FTS data sets (140 GB) are now on-line and searchable via a web-based query tool.

2. Upgraded Argo, the NSO data and web server, with a DLT-7000 tape drive, 512 MB additional
memory, and an additional 23-GB disk.

3. Installed an Agfa Duo-Scan high-resolution flat bed scanner, Mentalix PFscan, and Adobe Photoshop
on Argo. The system can accommodate glass plates, and will be used to scan historical solar plates
for inclusion in the digital library.
VII. SCIENTIFIC STAFF PERSONNEL STATISTICS

A. Hired

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Position</th>
<th>NOAO Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/01/97</td>
<td>Abijit Saha</td>
<td>Associate Astronomer/Tenure</td>
<td>KPNO</td>
</tr>
<tr>
<td>10/24/97</td>
<td>Shoko Sakai</td>
<td>Research Associate</td>
<td>KPNO</td>
</tr>
<tr>
<td>11/15/97</td>
<td>Edward Rosenthal</td>
<td>Scientist</td>
<td>KPNO</td>
</tr>
<tr>
<td>11/15/97</td>
<td>Charles Prosser</td>
<td>Research Associate</td>
<td>KPNO</td>
</tr>
<tr>
<td>01/12/98</td>
<td>David Devine</td>
<td>Research Associate</td>
<td>STIS</td>
</tr>
<tr>
<td>03/01/98</td>
<td>Meena Sahu</td>
<td>Research Associate</td>
<td>STIS</td>
</tr>
<tr>
<td>03/02/98</td>
<td>Carol Anne Grady</td>
<td>Research Associate</td>
<td>STIS</td>
</tr>
<tr>
<td>05/28/98</td>
<td>Stefan Haas</td>
<td>Research Associate</td>
<td>STIS</td>
</tr>
<tr>
<td>06/01/98</td>
<td>Travis Rector</td>
<td>Junior Scientist</td>
<td>KPNO</td>
</tr>
<tr>
<td>08/17/98</td>
<td>R. Chris Smith</td>
<td>Assistant Astronomer</td>
<td>CTIO</td>
</tr>
<tr>
<td>09/14/98</td>
<td>Ian Dell’ Antonio</td>
<td>Research Associate</td>
<td>KPNO</td>
</tr>
<tr>
<td>09/14/98</td>
<td>Knut Olsen</td>
<td>Research Associate</td>
<td>CTIO</td>
</tr>
<tr>
<td>09/25/98</td>
<td>Stefanie Wachter</td>
<td>Research Associate</td>
<td>CTIO</td>
</tr>
</tbody>
</table>

B. Completed Employment

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Position</th>
<th>NOAO Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>10/31/97</td>
<td>Larry November</td>
<td>Associate Astronomer</td>
<td>NSO/Sunspot</td>
</tr>
<tr>
<td>11/26/97</td>
<td>Arjun Dey</td>
<td>Research Associate</td>
<td>KPNO</td>
</tr>
<tr>
<td>05/22/98</td>
<td>Michael Keane</td>
<td>Research Associate</td>
<td>CTIO</td>
</tr>
<tr>
<td>06/30/98</td>
<td>Mark Phillips</td>
<td>Assistant Director/CTIO</td>
<td>CTIO</td>
</tr>
<tr>
<td>07/31/98</td>
<td>Matt Penn</td>
<td>Junior Scientist</td>
<td>NSO/Tucson</td>
</tr>
<tr>
<td>07/31/98</td>
<td>Jeff Kuhn</td>
<td>Astronomer/Tenure</td>
<td>NSO/Sunspot</td>
</tr>
<tr>
<td>08/17/98</td>
<td>Charles Prosser</td>
<td>Research Associate</td>
<td>KPNO</td>
</tr>
</tbody>
</table>

C. Changed Status

<table>
<thead>
<tr>
<th>Date</th>
<th>Name</th>
<th>Position</th>
<th>NOAO Division</th>
</tr>
</thead>
<tbody>
<tr>
<td>02/01/98</td>
<td>K. S. Balasubramaniam</td>
<td>Promotion from Assist. Scientist to Assoc. Scientist</td>
<td>NSO/Sunspot</td>
</tr>
<tr>
<td>02/01/98</td>
<td>Gary Bower</td>
<td>Promotion from Research Associate to Assistant Scientist</td>
<td>STIS</td>
</tr>
<tr>
<td>05/01/98</td>
<td>Mark Giampapa</td>
<td>Promotion from Assoc. Astronomer/Tenure to Astronomer/Tenure</td>
<td>NSO/Tucson</td>
</tr>
<tr>
<td>08/06/98</td>
<td>Christoph Keller</td>
<td>Promotion from Assoc. Astronomer to Assoc. Astronomer/Tenure</td>
<td>NSO/Tucson</td>
</tr>
<tr>
<td>08/10/98</td>
<td>Thomas Rimmele</td>
<td>Promotion from Assoc. Astronomer to Assoc. Astronomer/Tenure</td>
<td>NSO/Sunspot</td>
</tr>
<tr>
<td>08/31/98</td>
<td>Richard Dunn</td>
<td>Emeritus status granted</td>
<td>NSO/Sunspot</td>
</tr>
</tbody>
</table>
VIII. DIRECTOR'S OFFICE

The current management structure for NOAO consists of the following employees:

- Sidney Wolff, NOAO Director;
- Richard Green, KPNO Director/NOAO Deputy Director;
- Malcolm Smith, CTIO Director/NOAO Associate Director;
- Jacques Beckers, NSO Director/NOAO Associate Director;
- Todd Boroson, USGP/SCOPE Director/NOAO Associate Director;
- Robert Barnes, Assistant to the KPNO Director;
- Glen Blevins, Manager, Central Administrative Services;
- Larry Daggert, Manager, Engineering and Technical Services;
- John Dunlop, Manager, Central Facilities Operations;
- Yvette Estok, Manager, Public Information Office;
- Steve Grandi, Manager, Central Computer Services;
- Larry Klose, Manager, Central Administrative Services.

The NOAO Director is responsible for the overall operation of NOAO, which includes providing scientific leadership for NOAO, determining priorities, planning budgets, and allocating resources. The Director represents NOAO, and in particular, the four scientific divisions (CTIO, KPNO, NSO, and USGP/SCOPE) to AURA, NSF, and the scientific community.
IX. STATISTICS

During FY 1997 the KPNO and CTIO divisions of NOAO adopted a new database program to track observing proposals and programs scheduled on NOAO’s nighttime telescopes. To simplify the transition to the new system and to reduce the effort required long-term to provide statistical information on the effectiveness of NOAO’s nighttime telescopes, we are changing the reporting period for telescope statistics to coincide with the observing semesters at KPNO and CTIO. For the Annual Report covering the period 1 October 1997 through 31 September 1998, observing statistics will be reported from 1 August through 31 July. Other information included in the Annual Report will continue to cover the period from 1 October through 30 September.

A. CTIO

During the period 1 August 1997 through 31 July 1998, a total of 199 separate observing programs involving 473 scientists (230 visitors, 243 collaborators) were carried out at CTIO. In the same period, 159 papers were published based on the use of Cerro Tololo facilities. The number of nights CTIO scientific staff spent on CTIO during this period was 219. The number of public visitors to CTIO during this same period is estimated to be 6400.

CTIO Observational Statistics

The figures in the following table reflect the number of observers/users physically present at the Observatory and do not include multiple visits by a single observer/user. This table does not include NOAO staff. The total number of visits including multiple ones is 300. Visiting astronomers were assigned 92.6% of the observing time and the remaining 7.4% was assigned to the staff.

<table>
<thead>
<tr>
<th>CTIO Users by Category</th>
<th>US</th>
<th>Latin A.</th>
<th>Foreign</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhDs</td>
<td>102</td>
<td>15</td>
<td>39</td>
<td>156</td>
</tr>
<tr>
<td>Graduate Students</td>
<td>42</td>
<td>4</td>
<td>15</td>
<td>61</td>
</tr>
<tr>
<td>Technicians &amp; Research Students</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Total visitors</td>
<td>149</td>
<td>25</td>
<td>56</td>
<td>230</td>
</tr>
<tr>
<td>Collaborators (not physically present)</td>
<td>159</td>
<td>15</td>
<td>69</td>
<td>243</td>
</tr>
</tbody>
</table>

Total institutions represented by the above visits: 93

US Institutions (56)
- American Inst. of Physics
- Arizona State U.
- Bell Labs.
- Carnegie Inst. of Washington
- Columbia U.
- Cornell U.
- Eureka Scientific
- Georgia State U.
- Harvard-Smithsonian
- Harvard U.
- Johns Hopkins U.
- Lawrence Livermore Nat. Lab.
- Los Alamos National Lab.
- Louisiana State U.
- Macalester College
- Massachusetts Inst. of Tech.
- Michigan State U.
- Middlebury College
- NASA Ames
- NASA Goddard
- New Mexico State U.
- Northern Arizona U.
- Ohio State U.
- Pennsylvania State U.
- Rice U.
- Rutgers U.
- Space Telescope Science Inst.
- State U. of New York
- U. of Alabama
- U. of Arizona
- U. of California, Berkeley
- U. of California, Davis
- U. of California, Irvine
- U. of California, Santa Cruz
- U. of California, San Diego
- U. of Chicago

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During the period of 1 August 1997 through 31 July 1998, a total of 244 scientific programs, 52 of which were thesis programs, were carried out at the Kitt Peak facilities. Associated with these programs were 577 individual scientists. Astronomers using the observatory during this period represented 99 US institutions and 66 foreign institutions. The top five represented were:

- Space Telescope Science Institute (35)
- NASA Goddard Space Flight Center (24)
- Harvard-Smithsonian Center for Astrophysics (21)
- University of Colorado (17)
- University of Arizona (13)

### KPNO Users by Category

<table>
<thead>
<tr>
<th>Observers/Users</th>
<th>US</th>
<th>Foreign</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhDs</td>
<td>327</td>
<td>93</td>
<td>420</td>
</tr>
<tr>
<td>Graduate Students not observing for a thesis</td>
<td>43</td>
<td>6</td>
<td>49</td>
</tr>
<tr>
<td>Graduate Students observing for a thesis</td>
<td>38</td>
<td>9</td>
<td>47</td>
</tr>
<tr>
<td>Undergraduate Students</td>
<td>17</td>
<td>0</td>
<td>17</td>
</tr>
<tr>
<td>Other</td>
<td>44</td>
<td>0</td>
<td>44</td>
</tr>
<tr>
<td><strong>Total Visitors</strong></td>
<td>469</td>
<td>108</td>
<td>577</td>
</tr>
</tbody>
</table>
C. NSO

During the period of 1 August 1997 through 31 July 1998, a total of 175 observing programs, involving 88 individual scientific visitors as well as 20 scientific and 9 technical staff, were carried out at NSO facilities. During the same period, staff and users of NSO facilities published 126 papers. Astronomers using NSO facilities during this period represented 28 US institutions and 10 foreign institutions. Visiting astronomers were assigned 33% of the scheduled telescope time and the remaining 67% was assigned to staff.

During the reporting period a total of 454 identifiable outside users from 2113 sites accessed the main NSO/Tucson data archive and distribution area a total of 16,600 times. A total of 16,643 data files were transferred during these accesses. In addition, 23 distributions per observing day are made automatically to outside users, adding approximately 5500 distributions per year for a total of over 26,000 data distributions annually to about 650 users. During this same time period, NSO web pages were accessed by outside users a total of 66,569 times. Note that these statistics are for NSO/Tucson only.

<table>
<thead>
<tr>
<th>Observers/Users</th>
<th>US</th>
<th>Foreign</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhDs</td>
<td>69</td>
<td>13</td>
<td>82</td>
</tr>
<tr>
<td>Graduate Students</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td><strong>Total visiting users</strong></td>
<td><strong>73</strong></td>
<td><strong>15</strong></td>
<td><strong>88</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Institutions represented by the above visits</th>
<th>US</th>
<th>Foreign</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>28</td>
<td>16</td>
<td>38</td>
</tr>
</tbody>
</table>

D. NOAO Tucson Headquarters Building Statistics

During the period 1 October 1997 through 31 July 1998, a total of 1,392 visitors signed in at the NOAO Tucson headquarters building.
The following papers were published by Central Computer Services (CCS) personnel:


The following papers were published by Engineering and Technical Services (ETS) personnel:

ANNUAL REPORT
APPENDIX B

Cerro Tololo Inter-American Observatory
October 1997 through September 1998 Publications List


B-1


B-8


Cornett, R.H., Smith, E.P., Oegerle, W.R. et al., “Ultraviolet Imaging of the z = 0.23 Cluster Abell 2246”


C-6


C-10


Nikitin, A., et al. 1997, J. Molec. Spectrosc., 184, p. 120, "The High Resolution Infrared Spectrum of CH3D Lines in the Region 900-1700 cm⁻¹"


