

# **National Solar Observatory**



# NSO Annual Report FY 2003 October 1, 2002 – September 30, 2003

Submitted to the National Science Foundation Under Cooperative Agreement No. AST-0132798 (SPO No.2)

December 5, 2003

Also published on the NSO Web site: http://www.nso.edu



NSO is operated by the Association of Universities for Research in Astronomy under cooperative agreement with the National Science Foundation



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#### **1 INTRODUCTION**

This report summarizes scientific, operational, and programmatic activities at the National Solar Observatory (NSO) for the period 01 October 2002 to 30 September 2003.

The NSO, with facilities on Kitt Peak (KP) nearTucson, at Sacramento Peak (SP) in New Mexico, as well as at several other sites distributed globally, is operated by the Association of Universities for Research in Astronomy, Inc. (AURA), for the National Science Foundation (NSF). The mission of NSO is to advance knowledge of the Sun, both as an astronomical object and as the dominant external influence on Earth, by providing forefront observational opportunities to the research community. The NSO fulfills its mission by operating cutting-edge facilities, by leading the development of advanced instrumentation in collaboration with the solar physics community, and by conducting solar and related research. The NSO is also active in the conduct of educational and public outreach programs.

NSO facilities for observing and data reduction are available to the entire astronomical community. The NSO Home Page, accessible through the World Wide Web at <u>http://www.nso.edu/</u>, provides on-line information about NSO services, including telescope schedules, instrument availability, and information about how to apply for telescope time.

AURA is a private, non-profit corporation that operates world-class astronomical observatories through its operating centers. NSO is an operating center managed by AURA under cooperative agreement with the NSF. More information on AURA and its organizational structure can be found at *http://www.aura-astronomy.org/*.

The NSO reached several key milestones in its multi-year program to renew national ground-based solar observing facilities. Among these milestones were the successful completion of the Conceptual Design Review for the 4-meter Advanced Technology Solar Telescope (ATST); the deployment of the Vector Spectromagnetograph (VSM) of the new Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility to its test site in Tucson prior to its installation on Kitt Peak at the site of the former Kitt Peak Vacuum Telescope (KPVT); commencement of operations of the upgraded Global Oscillation Network Group (GONG); implementation of the second phase of the Diffraction-Limited Stokes Polarimeter (DLSP), an up-grade of the Advanced Stokes Polarimeter (ASP); and initiation of the development of a prototype for the Virtual Solar Observatory (VSO). The major components of the NSO long-range plan include: continuing to lead the development of the 4-m ATST; developing adaptive optics (AO) systems that can fully correct large-aperture solar telescopes; deploying and operating the instruments comprising SOLIS; operating GONG in its new high-resolution mode (GONG<sup>++</sup>); and, collaborating with the community in the establishment of the Virtual Solar Observatory for the archiving and dissemination of solar data. These new and planned instruments and facilities, as the principal foundations of the NSO along with its scientific staff, are key elements in a vigorous program of scientific leadership by the United States in ground-based solar physics.

The NSO encourages broad community involvement in its programs through partnerships to build instruments, develop new facilities and to conduct scientific investigations. Agreements have been established with the High Altitude Observatory (HAO), the New Jersey Institute of Technology (NJIT)/Big Bear Solar Observatory (BBSO), the University of Hawaii, the University of Chicago, and the University of California San Diego for their efforts in the ATST collaboration. Agreements with other members of the twenty-two institutions that proposed to NSF for the design and development of the ATST are being developed as needed. NJIT/BBSO, the Air Force Research Laboratory (AFRL) and the Kiepenheuer Institute (KIS) in Freiburg are continuing their

collaboration with NSO to develop high-order solar adaptive optics. NSO and HAO have begun Phase II in the development of the Diffraction-Limited Stokes Polarimeter, a high-resolution version of the Advanced Stokes Polarimeter that will take full advantage of adaptive optics to measure small-scale solar magnetic fields, and will enable diffraction-limited polarimetry at the Dunn Solar Telescope (DST). The NSO is in discussion with potential international partners that are interested in the establishment and operation of a SOLIS/VSM global network. The NSO also maintains active contacts with colleagues in the solar radio community in the context of the development of FASR, the Frequency Agile Solar Radio telescope facility. The NSO works closely with the Air Force, National Aeronautics and Space Administration (NASA), and the National Optical Astronomy Observatory (NOAO) to provide critical synoptic observations that, in addition to producing noteworthy science, also support space weather monitoring and prediction as well as space and other ground-based observations.

#### 2 SCIENTIFIC AND KEY MANAGEMENT PERSONNEL

The NSO staff is located in Sunspot, New Mexico and Tucson, Arizona. The observatory Director is Dr. Stephen L. Keil, who is based in Sunspot but spends time at both operational sites. Dr. Mark Giampapa is Deputy Director and responsible for the Tucson operations. Mr. Rex Hunter is Site Manager at Sacramento Peak at Sunspot. Mr. Jim Oschmann is the ATST Project Manager, while Mr. Jeremy Wagner serves as the ATST Deputy Project Manager and SOLIS Project Manager. Ms. Patricia Eliason is the GONG Facility Manager, and Mr. Dave Dooling is the ATST/NSO Educational Outreach Officer. NSO and affiliated scientific staff are listed below, along with their primary area of expertise and key observatory responsibilities.

#### 2.1 Sunspot Based Staff

#### NSO Staff

- K. S. Balasubramaniam Solar activity; magnetism; polarimetry; Ch., NSO/SP Telescope Allocation Committee; Co-Site Director, NSO REU/RET Program.
- Alexei A. Pevtsov Solar activity; coronal mass ejections.
- Thomas R. Rimmele Solar fine structure and fields; adaptive optics; instrumentation; ATST Project Scientist; Ch., Sac Peak Project Review Committee.
- Han Uitenbroek Atmospheric structure and dynamics; radiative transfer modeling of the solar atmosphere.

#### Grant-Supported Staff at Sunspot

- K. Sankarasubramanian Solar fine structure; magnetism; stokes polarimetry.
- Gilberto Moretto Optical instrumentation; adaptive optics.
- Maud Langlois (NJIT) Adaptive optics (high-order AO and multi-conjugate AO); instrumentation.

#### Air Force Research Laboratory Staff at Sunspot

- Richard C. Altrock Coronal structure and dynamics.
- Nathan Dalrymple Polarimetry; thermal analysis.
- Joel Mozer Coronal structure; remote sensing; space weather.
- Donald F. Neidig Solar activity; Project Scientist, Improved Solar Observing Optical Network (ISOON).
- Richard R. Radick Solar/stellar activity; adaptive optics.

#### 2.2 Tucson-Based Staff

• Mark S. Giampapa – Stellar dynamos; stellar cycles; magnetic activity; NSO Deputy Director; Ch., Tucson Project Review Committee; SOLIS PI.

- John W. Harvey Solar magnetic and velocity fields, helioseismology, instrumentation; SOLIS Project Scientist; Ch., NSO/KP Telescope Allocation Committee.
- Carl J. Henney Solar MHD; polarimetry; space weather; SOLIS Facility Scientist
- Frank Hill Solar oscillations; data management.
- Rachel Howe Helioseismology; the solar activity cycle.
- Christoph U. Keller Solar polarimetry; adaptive optics; instrumentation.
- Shukur Kholikov Helioseismology; data support.
- John W. Leibacher Helioseismology; GONG PI.
- Matthew J. Penn Solar atmosphere; solar oscillations; polarimetry; near-IR instrumentation; Co-Site Director, NSO REU/RET Program.
- Jeffrey J. Sudol Helioseismology; data support.
- Clifford Toner Global and local helioseismology; image restoration; data analysis techniques.

#### Grant-Supported Staff in Tucson

- Michael Dulick Molecular spectroscopy; high-resolution Fourier transform spectrometry.
- Irene E. Gonzalez-Hernandez Helioseismology; data support.
- Rudolph W. Komm Helioseismology; dynamics of the convection zone.
- Elena Malanushenko Structure of the solar chromosphere and transition region; coronal holes; operations and data support.
- Roberta Toussaint Helioseismology; image calibration and processing; data analysis techniques.

#### NASA Staff in Tucson

• Harrison P. Jones – Solar magnetism and activity.

## **3** SCIENTIFIC RESEARCH

Use of NSO facilities produces a significant number of research papers each year while also providing solar data that support a wide range of solar and solar terrestrial studies and solar activity forecasting. The latter includes data in support of space missions such as SoHO, RHESSI and TRACE and data sent to the NOAA Space Environment Center in Boulder for predicting and understanding solar activity. NSO makes solar data available to a diverse community of scientists and educators through its Digital Library (*http://diglib.nso.edu/*). Some of NSO's recent science highlights are described in the following section.

# 3.1 Signatures of Large-Scale Coronal Eruptive Activity, Associated Flares, and Propagating Chromospheric Disturbances

On 19 December 2002 at approximately 21:50 universal time, D. F. Neidig (AFRL/VSBXS), K. S. Balasubramaniam, A. A. Pevtsov (NSO), E. W, Cliver (AFRL-VSBXS), C. A. Young (EER Systems, NASA-GSFC), S. F. Martin (Helio Research), and A. L. Kiplinger (U. Colorado) obtained multi-wavelength data sets that, upon analyses, show evidence of a large-scale, transequatorial coronal eruption associated with simultaneous flares in active regions in both hemispheres. The coronal manifestations, based on the Solar and Heliospheric Observatory (SoHO), Extreme ultraviolet Imaging Telescope (EIT), Large Angle and Spectrometric Coronagraph Experiment (LASCO), and Transition Region and Coronal Explorer (TRACE) images, include a large coronal dimming, an opening/restructuring of magnetic fields, the formation of a transient coronal hole, and a halo coronal mass ejection (CME). In the chromosphere, Improved Solar Observing Optical Network (ISOON) Hα images show distant flare precursor brightenings and several sympathetic flares.

Originating near the main flare is a rapidly propagating (800 km/s), narrowly channeled disturbance that is detectable through the sequential brightening of numerous pre-existing points in the H $\alpha$  chromospheric



are all the same polarity. The coronal manifestations of this large-scale event include transequatorial loops, and coronal dimming, as observed by SoHO/EIT. These and similar events recorded by ISOON show that such large scale coronal eruptive events trigger near simultaneous surface activity separated by distances on the same scale as coronal structures involved in the eruption.

network. This disturbance is not a chromospheric Moreton wave, but it does produce a temporary activation of a transequatorial filament. This filament does not erupt, nor do any of the other filaments in the vicinity. Michelson Doppler Imager (MDI) magnetograms show that the brightened network points are all of the same polarity (the dominant polarity among the points in the disturbance's path), suggesting that the affected field lines extend into the corona, where they are energized in sequence as the eruption tears away.

Three other similar eruptive events (non-transequatorial) that we studied, while less impressive, show most of the same phenomena, including distant sympathetic flares and a propagating disturbance showing close adherence to the monopolarity rule. Two of these events include filament eruptions near the main flare. The investigators conclude that the observations of these four events are consistent with large-scale coronal eruptive activity that triggers nearly simultaneous surface activity of various forms separated by distances on the same scale as the coronal structures themselves. A filament eruption at the main flare site does not appear to be a necessity for this type of eruptive activity.

#### 3.2 Infrared Molecular Lines Reveal Rapid Outflow in Sunspot Penumbral Fibrils

The Evershed effect is a horizontal outflow of plasma from the inner region of a sunspot toward the quiet Sun and is observed in the penumbra of sunspots. Spectroscopic observations of the Evershed flow use the fact that the mainly horizontal flow, when observed in sunspots near the edge of the Sun, produces a line-of-sight Doppler shift due to the geometric projection involved. Observations of lines from neutral atoms, particularly Fe, show a more complicated situation, however, producing line asymmetries rather than simple Doppler shifts, due to seeing effects and the formation properties of the spectral line in the solar atmosphere.



FIG. 2. Background image from the NSO Kitt Peak Vacuum Telescope at 869 nm showing the disk position of NOAA 10008 on 29 June 2002. The two inset images show continuum maps of the spot region, with the penumbral bins and spot azimuth directions shown in the left inset. The penumbral spectra were binned in 16 azimuthal bins. An azimuth of 90 degrees is defined as toward the center of the solar disk.





New observations of the Evershed flow by M. J. Penn and W. C. Livingston (NSO), W. Cao (NJIT/Yunnan Observatory), and S. R. Walton and G. A. Chapman (Cal State Northridge), using a CN molecular absorption line at 1564.6 nm, reveal a different situation. Since the CN line is formed only in the cool temperatures found in the dark penumbral fibrils, the spectroscopic properties of the line will only reflect the physical conditions present in the dark fibrils, independent of seeing or other spatial averaging. Measurements were made of several sunspots using the NSO-Cal State Northridge infrared (IR) camera and spectropolarimeter during June 2002 at the McMath-Pierce telescope. To improve the spectral signal-to-noise of the data, a plane-polar coordinate system was calculated (see Fig. 2) and the raw spectra were averaged into 16 azimuthal bins (using about 300 raw spectra per bin). The spectra were then plotted as a function of azimuthal angle, and the Doppler signature of an outflow was readily apparent. Observations of sunspot NOAA 10008 on three days show Evershed outflows as a Doppler shift of the CN line, with a typical velocity of 6 km/sec (see Fig. 3). A similar behavior was seen with spectral

lines at 2231 nm. A temperature-sensitive Ti line, and an unidentified molecular line (which shows a temperature dependence similar to CN) exhibited similar characteristic outflows. The polarimetric observations of the Ti line implied a mean penumbral magnetic field of 1400 gauss in these outflow regions.

## 3.3 GONG

During FY 2003, the GONG high-spatial resolution system made excellent progress towards achieving routine scientific operations. While the "ring-diagram" analysis that yields sub-surface solar weather flows remains the principal technique being exploited, the other two methodologies—"time-distance" and "acoustic holography"— are being implemented as is imaging of the Sun's back, or farside, which with near-real time data should provide a predictive capability for the space weather community. Results are already beginning to come out of the high time cadence magnetograms, which should enable yet another new community of users of GONG data.



FIG. 4. See reference to figure in text (Sec. 3.3).

The transit of Mercury (Fig. 4) provided a rare opportunity to achieve extremely high-fidelity, absolute- geometry measurements of the instruments and the network. The figure, which shows the planet every 15 minutes as it appears to move across the Sun, illustrates nicely the capability of the network to provide uninterrupted solar observations—from Learmonth in Western Australia, where the transit began during the local afternoon and was still in progress at sunset, to Udaipur in Rajasthan, where the entire transit was visible, to Teide in the Canary Islands, where the transit was in progress at sunrise. These images were obtained in real time and made available on the Web, where they enjoyed a quarter million "hits" during the transit, in spite of the fact that it occurred at night for the Americas. This is just a warm up for the transit of Venus that will occur in 2004.

See Sec. 5.1 for more details about GONG.

## 3.4 X-Ray Radiance and Magnetic Flux

The outer solar atmosphere—the corona—has a temperature of more that 1 million degrees. Similar hot coronae exist around many other stars. Whether the same mechanism heats the solar and stellar coronae is a significant question. The relationship between magnetic and radiative fluxes may provide some answers.

A. A. Pevtsov (NSO), in collaboration with G. H. Fisher (UC Berkeley), L. W. Acton, D. W. Longcope and C. C. Kankelborg (Montana State), C. M. Johns-Krull (Rice U.), and T. R. Metcalf (Lockheed Martin), is studying a correlation between magnetic and X-ray fluxes using observations of the Sun (quiet Sun, X-ray bright points,

active regions and integrated solar disk), and dwarf and pre-main sequence stars. For solar objects, data were used from the soft X-ray telescope (SXT) on board the Yohkoh satellite, and magnetograms from three different instruments: the NSO/Kitt Peak spectromagnetograph, the Michelson Doppler Imager on board SoHO, and the University of Hawaii Stokes Polarimeter at Haleakala. The X-ray radiance and total magnetic flux of 16 dwarf stars (types G, K and M) and 6 T-Tauri stars are computed using X-ray surface flux, magnetic field strength, and magnetic filling factor observed by Saar (1996), Johns-Krull and Valenti (2000) and Johns-Krull et al. (2001).

Fig. 5 shows the relationship between total unsigned magnetic flux and X-ray spectral radiance for all 6 data sets. With one exception (T-Tauri), all objects show statistically significant correlation between X-ray and magnetic flux. Deviation of 5 T-Tauri stars from general dependence might be the result of selection effects or X-ray absorption in the stellar wind. It might also indicate the saturation of coronal heating on these stars, whose surface is completely covered by strong magnetic fields.



FIG. 5. X-ray spectral radiance  $L_x$  vs. total unsigned magnetic flux for solar and stellar objects: quiet Sun (QS), X-ray bright points (XBP), solar active regions (Ars), solar disk averages (Sun), G, K, and M dwarfs, and T-Tauri stars. The dashed line represents the power-law approximation  $L_x \alpha \Phi^{1.15}$  of the combined data set.

The individual subsets are different in scattering and functional dependency between magnetic and X-ray fluxes. One can think of several explanations for such "individuality." In a quiet corona, the magnetic field, expanding with height, may form a bright canopy above neighboring magnetically independent areas, and thus affect the relationship between magnetic and X-ray fluxes. In solar disk averages, the relationship may be distorted by the presence of coronal holes. The coronal holes have reduced X-ray flux, but their unsigned magnetic flux is comparable to brighter quiet-Sun areas.

Nevertheless, despite all possible complications, the combined data follow one simple dependency. Over a great diversity in spatial scales and magnetic flux densities, the X-ray output of coronal plasma is roughly proportional to the unsigned magnetic flux threading the solar or stellar photosphere. The simple, near linear relationship suggests a common heating mechanism, although the level of scatter about that relationship indicates that detailed morphology also plays an important role.

#### 3.5 Solar Ha Zeeman Spectropolarimetry

The H $\alpha$  spectral line at 6562.808 Å is an exceptional spectral line in its sensitivity to chromospheric activity. However, inferring magnetic fields in H $\alpha$  (or for that matter, any chromospheric spectral line) is difficult because the spectral line is formed under a complicated set of non-LTE conditions.

K. S. Balasubramaniam (NSO), E. B. Christopoulou (U. Patras, Greece; 2001 NSO Summer Research Assistant) and H. Uitenbroek (NSO) are researching the Zeeman spectro-polarimetric properties of Hα observed in a sunspot using the HAO/NSO Advanced Stokes Polarimeter.

Comparing Stokes V profiles of photospheric lines (Fe I  $\lambda$ , 6301.5 Å and 6302.5 Å) with that of H $\alpha$ , it was found that the Stokes V profiles are easily seen in sunspots and active regions, and at the site of flares (marked by an "o" in Fig. 6), where the core of Stokes intensity profile in H $\alpha$  is seen to undergo a self reversal. The Stokes V profile in the core of the spectral line is formed in absorption, while in the wing of the spectral line it is formed in emission. This causes a polarization double reversal. In Fig. 7, this double reversal is shown as a plot, comparing it with a normal Stokes V in the umbra. If not correctly interpreted, this exceptional behavior of H $\alpha$  showing the normal and the inverse Zeeman effect can lead to the misinterpretation that magnetic fields in the umbral chromosphere are reversed. The authors have reproduced the H $\alpha$  Zeeman self reversal using complete radiative transfer of the spectral line, including partial redistribution, in a strong magnetic field, and under the influence of a model flare atmosphere.



FIG. 6. Comparison of Stokes I and V profiles in the 6300 Å region (left panels) and  $H\alpha$  (right panels).

FIG. 7. Plot of normal and double-reversed polarization profiles.

#### **4 MAJOR PROJECTS**

#### 4.1 Advanced Technology Solar Telescope (ATST) Project

The FY 2002 annual report described early progress of a community-wide project to develop the next generation, facility-class telescope to advance high-resolution solar physics and the measurement of solar magnetic fields—the Advanced Technology Solar Telescope. What follows is an update of the progress on the ongoing ATST design effort as well as the construction proposal efforts.

With its 4-meter aperture and integrated adaptive optics, the ATST will resolve areas on the Sun over an order of magnitude smaller than current meter-class solar telescopes. Its high photon flux and broad spectral coverage will allow it to make sensitive magnetic field observations at heights from the photosphere into the corona. Observations have established that the photospheric magnetic field is organized in small fibrils, or flux tubes, with sizes below current resolution limits. Theory and models predict that these fibrils have scales of just a few tens of kilometers ( $\leq$  30 km) and that they play fundamental roles in solar dynamo processes, atmospheric heating, and solar activity. Resolving and measuring the properties of the magnetic field at its fundamental scale is thus a primary goal for the ATST. A complete description of science goals, and project information, can be found at *http://atst.nso.edu*.

#### 4.1.1 ATST Science Working Group (SWG)

Current membership of the Science Working Group can be found at *http://atst.nso.edu/swg/members.html*. The SWG met several times during the past year to quantify many of the preliminary observing capabilities specified for the ATST to meet its science goals. For example, the measurement of small magnetic flux elements generates specifications for aperture size, polarization accuracy and sensitivity, atmospheric and telescope seeing properties, scattered light, and instrument performance. Table 1 lists the toplevel requirements specified in the Science Requirements Document (SRD).

More detailed requirements and derived observational performance requirements can be found in the SRD. The SRD is a living document that will evolve as trade studies are completed and risks assessed. It is available on the ATST WWW site, or directly from Project Scientist Thomas Rimmele (*rimmele@nso.edu*). Community inputs into the requirements and ATST science capabilities are welcome.

#### **TABLE 1. Summary of Top-Level Science Requirements**

Aperture	4 m
FOV	3 arcmin minimum; goal of 5 arcmin
Resolution	Conventional AO Case: Diffraction limited within isoplanatic patch for visible and IR wavelengths. MCAO (upgrade option): Diffraction limited over >1 arcmin FOV.
Adaptive Optics	Strehl (500nm): >0.3 median seeing; >0.6 good seeing
Wavelength Coverage	300 nm - 28 μm
Polarization Accuracy	Better than 10 <sup>-4</sup> of intensity
Polarization Sensitivity	Limited by photon statistics down to 10 <sup>-5</sup> $\rm I_{c}$
Coronagraphic	In the NIR and IR
Instruments	Well instrumented - access to a broad set of diagnostics, from visible to thermal infrared wavelengths.
Operational Modes	Flexibility to combine various post focus instruments and operate them simultaneously; Flexibility to integrate user supplied instruments.
Lifetime	30 – 40 years

### 4.1.2 ATST Project Organization

There have been no significant changes to the ATST project organization over the past year (see Fig. 8). The project team draws from a broad range of resources, which include new hires, contributions from members of the existing NSO staff and individuals from other organizations, as well as efforts by Co-PI and collaborating teams.

The engineering team reports to Jim Oschmann and the science team to Thomas Rimmele. Steve Keil is the Project Director.



FIG. 8. ATST Organizational Chart.

The Co-PI's and other collaborating institutions participate in both design and science activities. Agreements for the primary efforts in instrumentation and support of the site survey have been established through MOU's. The following agreements are in place:

- High Altitude Observatory (Visible Light Polarimeter Design; Near IR Polarimeter Contributions).
- University of Hawaii (Sky Brightness Monitor and Dust Monitor; Near IR Polarimeter Design (Lead); Site Survey Operations on Haleakala and Mauna Kea).
- University of Chicago (Site Survey Project Engineer; Theoretical Support for Science Working Group).
- New Jersey Institute of Technology (Site Survey Operations at Big Bear; Tunable IR Filter Design).
- University of California, San Diego (Scattered Light Trade Studies).

The project continues to seek additional participation by international collaborators.

Contracts have been established with Lockheed for the broadband filter design and with Photon Engineering in Tucson for additional stray light studies. Several polishing contractors are conducting mirror polishing feasibility studies. Other contractors are evaluating the enclosure design, mount, and primary mirror systems.

## 4.1.3 Design Progress

Design activities during the past year were focused on the completion of several major trades, systems engineering flow-down of requirements, initial performance modeling, and related activities leading to the conceptual design review (CoDR) that was held in August 2003. A list of major trades that were completed for the CoDR follow:

#### • Conceptual Design Review (August 2003)

#### Major trades:

- Telescope mount configuration (Alt-Az vs. equatorial or Alt-Alt).
- Optical design concept (off-axis vs. on-axis).
- Enclosure concept (open, ventilated non-co-rotating, co-rotating, tightly integrated, closed).
- Instrument facility layout (Coudé, Nasmyth, Gregorian, etc.).
- First order analysis of system performance, for preferred approach(s).

Very early in the fiscal year, we were able to complete the first two major trades listed above. With the help of a community-based workshop and several external engineering consultants, we chose an Altitude-Azimuth configuration for the mount and confirmed our intent to use an off-axis optical design to miminize stray and scattered light concerns. This design has the benefit of allowing good access to the prime focus area for the infrastructure required to handle the thermal aspects of the heat stop, which must be water cooled.

For most of the year, our remaining efforts concentrated on the enclosure concept. A hybrid design (Fig. 8) was selected by the time of the CoDR in August. This concept is a co-rotating ventilated dome with external skin cooling. A ventilated dome allows the ability to minimize primary mirror, telescope structure, and internal dome air seeing, while having the flexibility to control telescope shake and mirror buffeting during high wind conditions. This design is used for all newer, large nighttime telescopes, but presents a new challenge for daytime viewing. During the day, the Sun will heat the dome structure unless it is actively cooled. Our concept pays particular attention to ventilation details and ensures that the dome will have minimum impacts on local seeing. A Computational Fluid Dynamics (CFD) analysis has been completed and the results look promising for optimizing dome ventilation.



FIG. 8. ATST layout design presented at CoDR.

With regard to the primary mirror, fabrication studies were completed in May by five institutions that are experienced in optics fabrication: Brashears; Goodrich Corp. (provided at no cost); Rayleigh Optical; SAGEM; and the University of Arizona Steward Observatory Mirror Lab. All vendors were confident that their proposed methods for manufacturing and testing our desired mirror arrangement would lead to a successful primary mirror effort. The design studies included manufacturing and polishing processes, test configuration design, testing, specification review, risks, schedule, and cost.

Thermal control concepts for the primary mirror and other optics have evolved with concentration on the primary and secondary mirrors. The thermal models have been updated to include seeing effects based upon work by Nathan Dalrymple (USAF/AFRL). These models were also extended to apply to mount and dome shell seeing. The latter was the primary technical concern of the efforts leading to the CoDR.

Work on the telescope mount included completion of a first-order, finite-element analysis of flexure and windshake, assuming a loose soil configuration. Details of the coudé lab design have evolved along with initial tolerance with respect to the optics.

As part of our efforts to obtain feedback and cost estimates on our design (beyond the CoDR process), the following companies have agreed to provide the project with input:

Optical Assem	blies: EOS Technologies; Goodrich Corp.; SAGEM; Brashear LP will give informal feedback at
	no cost.
Mount:	EOS Technologies; Telescope Technologies Ltd.; Vertex RSI; MAN Technologies may offer feedback and participate later.
Enclosure:	M3 Engineering & Technology Corp.: Vertex RSI: AMEC will provide evaluation at no cost).

To allocate requirements and assess performance at a systems level, Rob Hubbard and Jim Oschmann have made significant progress on the error budget for several key cases, including bottom-up performance modeling that includes statistical input from the sites in the area of seeing, wind and thermal properties. Tying these with Nathan Dalrymple's thermal modeling is providing a good assessment of the range of likely performance and identifies areas in need of detailed assessment and design.

#### 4.1.4 Site Survey

The choice of a site for the ATST is a critical aspect in its design. The dominant site requirements are: minimal cloud cover, many continuous hours of sunshine, excellent average seeing and many continuous hours of excellent seeing, good infrared transparency, and frequent coronal skies. In order to perform a quality site evaluation and selection for the ATST, an ATST Site Survey Working Group (SSWG) with broad community participation was established. This committee has representatives from other nations that have expressed interest in participating in the ATST.

The SSWG determined ATST siting criteria, is verifying the validity of the site testing procedures, and is preparing an interim report that contains the results of the data collection and analysis to date. This report will be provided to the Project Scientist, who will meet with the Science Working Group to prepare a ranked list of the sites on the basis of the scientific quality of the sites. The number of candidate sites will be reduced on the basis of this list, and the survey continued at those sites with additional testing instrumentation. The additional

instrumentation will assess the quality of specific locations within each site, and test more properties of the atmospheric turbulence.

Site survey towers and instrumentation have now been operating for 0.5-1.8 years at:

- Big Bear Solar Observatory, California;
- Mees Solar Observatory, Haleakala, Hawaii;
- Observatorio Rouque de Los Muchachos, La Palma, Canary Islands, Spain;
- Sacramento Peak, New Mexico;
- San Pedro Martir, Baja California, Mexico;
- Panguitch Lake, Utah.

A considerable quantity of data has been collected, and the Interim Report was publicly released in mid-November 2003.

#### 4.1.5 Plans

Project plans for FY 2004 begin with preparation of the ATST construction proposal. The work breakdown structure (WBS) and schedule for the construction phase is being developed in the same manner as the design and development phase. This includes major milestones such as final or fabrication reviews, measurable fabrication stages, acceptance, shipment, integration, testing, and commissioning. Each engineer responsible for a WBS element has been detailing the plans and schedules for individual areas within the WBS, including budgets. Contingency will be held centrally. Once the construction phase proposal has been submitted, the project efforts will focus on the preliminary design, which will culminate in a review later in 2004. Prioritization of tasks is based upon feedback from the CoDR, SWG review of the CoDR, and contractor feedback. The project budget status will determine the extent to which we continue to utilize major contractors throughout this phase.

Instrumentation designs will evolve to a conceptual level, again concentrating on impacts to the facility design. With the down selection of the site options scheduled for fall of 2003, we hope to begin environmental impact assessments for one or two sites and have detailed building designs started by summer of 2004, when the final site is selected.

In support of design activities, the error budget activity will be extended to include more site data and to improve modeling. With science objectives in mind, key observing scenarios need to be worked out to better understand and develop the engineering requirements for and design of the telescope. As stated in last year's report, the plan calls for two major reviews to be held during the design and development phase. These include:

#### • Preliminary Design Review (2004)

- Preliminary design of the baseline approach established during the conceptual design phase.
- Instrument integration and operational considerations.
- Involvement of partner and manufacturing organizations in the process where possible.
- Establishment of construction costs and contingency; including draft integration, testing and commissioning plans.
- Submission of Construction Phase proposal prior to Preliminary Design Review.

#### • Critical Design Review (2005)

- Preparing construction detailed design and specifications.
- Procurement planning.
- Integration, test and commissioning planning.
- Operational planning.

The details of these reviews will evolve as we move closer to them. Decisions on the level of contractor involvement, based upon initial evaluations in process, will affect the details, timing and format of these two remaining reviews. We are continue our efforts toward early procurement of the primary mirror blank.

## 4.2 High-Order Adaptive Optics (AO)

Since August 2000, the NSO, in primary partnership with the New Jersey Institute of Technology (NJIT), has been developing high-order solar adaptive optics for use at the 65-cm telescope at Big Bear Solar Observatory (BBSO) and the 76-cm Dunn Solar Telescope (DST) at Sacramento Peak. The National Science Foundation has sponsored this project within the Major Research Instrumentation program with substantial matching funds from the participating partner organizations, which include the NSO, the NJIT, the Kiepenheuer Institute in Germany, and the Air Force Research Laboratory. The high-order AO system will upgrade each of these high-resolution solar telescopes and greatly improve their scientific output. The resulting systems will also serve as proofs-of-concept for a scalable AO design for the much larger 4-meter Advanced Technology Solar Telescope. Compared to the low-order AO system currently operating at the DST, the high-order AO system provides a threefold increase in the number of deformable mirror actuators that are actively controlled.

Starting in December 2002, the high-order solar AO team achieved several major milestones. First, during the first engineering run at the DST, the servo loop was successfully closed on the new high-order AO system for the first time. At this point the system used a DALSA camera, which operates at 955 frames per second, as the interim wavefront sensor. The optical setup was not finalized and preliminary, "bare-bones" software operated the system.

The goal of these tests was to demonstrate that all the components work together as a system. Even in this preliminary state, the AO system delivered impressive image quality. It was demonstrated that even in mediocre seeing conditions, diffraction-limited imaging can be provided by the high-order AO system. Time sequences of corrected and un-corrected images show that the new AO system provides fairly consistent high-resolution imaging even as the seeing varies substantially, as is typical for daytime conditions.

In April 2003, the high-order AO system was turned on for the first time with the new high-speed wavefront sensor camera. This camera is based on a CMOS device and operates at a rate of 2500 frames per second, which more than doubles the closed-loop servo bandwidth of the system compared to the DALSA camera. The camera was custom developed for the AO project by BAJA Technologies and lead AO project engineer, Kit Richards of NSO. Richards also implemented improved control software for the April engineering run.



FIG. 9. Image of an active region with (left) and without (right) AO correction. The field of view is  $45 \times 45$  arcsec with a wavelength of 550 nanometers. The AO was locked onto the dark structure in the center of the field of view.

The tip/tilt mirror can now be driven either directly from the AO wavefront sensor or from a separate correlation/spot tracker system that operates at a 3 kHz rate. Figure 9 shows an image of an active region taken

with the AO loop closed and with the AO system off. Under seeing conditions that normally would preclude high-resolution images, the high-order system with its high, closed-loop bandwidth provided excellent imaging.

During the latter part of this fiscal year, the project focused on completing the optical setup at the DST, installing the BBSO AO bench, conducting engineering runs at BBSO, optimizing reconstruction matrices and servo loop controls, and characterizing the system performance at both sites. Commissioning of the DST system was completed in fall of 2003. The Diffraction-Limited Spectro-Polarimeter (DSLP), the main science instrument that can take advantage of the diffraction-limited image quality delivered by the high-order AO, also performed its first commissioning runs in fall of 2003 (see Sec. 5.5.2).

## 4.3 SOLIS

SOLIS (Synoptic Optical Long-term Investigations of the Sun) is a project to obtain 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 required five years. The 25-year operational phase of the major instrument started late in FY 2003.

A Science Advisory Group provides expert advice from a wide range of the user community. The High Altitude Observatory, Lockheed-Martin Solar and Astrophysics Laboratory, Office of Naval Research, and NASA have been active partners in the SOLIS program.

As funded, SOLIS comprises three instruments that will initially be mounted on the top of the existing Kitt Peak Vacuum Telescope. The mounting is transportable so that SOLIS can be moved to a different site in the future. The three full-disk instruments on a common mount are:

(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 spectral line characteristics of the helium chromosphere. (2) A Full-Disk Patrol (FDP) that provides digital, one-arcsec pixel 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) that furnishes Sun-as-a-star spectra at both high and medium spectral resolutions with emphasis on high photometric precision and stability.

A major component of SOLIS is data processing, distribution, and archiving. SOLIS will be most productive when working in concert with other observing projects, both in space and on the ground. In particular, operating space missions, including the Solar and Heliospheric Observatory (SoHO), Transition Region and Coronal Explorer (TRACE), and Ramaty High Energy Solar Spectroscopic Imager (RHESSI), and future missions such as the Japanese SOLAR-B (09/2005) and NASA's Solar TErestrial Relations Observatory (STEREO) (11/2005) and Solar Dynamics Observatory (SDO) (04/2008).

This report covers the period October 2002 through September 2003 of the assembly, testing, and startup phases of the 25-year SOLIS project. During this period, emphasis was on assembly and testing of major elements of the SOLIS system, and initial observing with the VSM.

A major milestone was achieved when the VSM was mounted on the SOLIS mounting (temporarily located at the University of Arizona Campus Agricultural Center) and received first sunlight. Prior to this, optics coated with high-reflectivity silver films had degraded, were recoated, then kept in an oxygen-free environment, except

for some alignment periods. This strategy was successful, as the coatings installed in the VSM appear to be excellent, while witness samples exposed to air have once again degraded.

At first, sunlight was gradually admitted to the helium-filled VSM until it was confirmed that the active cooling system worked as expected. Tests showed that the grating motion range was less than expected, so a temporary "clean room" was constructed around the VSM using plastic sheeting and duct tape. The sealed VSM was opened and the grating motion problem was repaired. Additional software and wiring problems were located and repaired, and daily observations started in mid-August 2003. These observations were coordinated with similar observations taken at the NSO Kitt Peak Vacuum Telescope in order to link the 30-year record of old observations with the new VSM data. The coordinated observing continued for a month and the old instrument was shut down on 22 September 2003. Since then, the regular synoptic observing program has been done with the VSM, and the Kitt Peak facility is being prepared to receive the SOLIS instruments.

The VSM observations have confirmed the concept of the instrument. For a similar observing duration, the VSM data are more than 20 times quieter than the old data. The new data are free of instrumental polarization effects and have a negligible zero-point offset. When the seeing is good at the present location of the VSM, the image quality is excellent. These characteristics indicate that the VSM will be the "gold standard" of moderate spatial resolution magnetograph instruments. What is thought to be the first ever full-disk vector magnetogram was taken on 30 August 2003. It shows that the vector field can be measured in the quiet Sun magnetic network and polar field regions as well as within active regions. As had been expected, the magnetic network fields appear to be nearly normal to the solar surface. In October 2003, a time series of vector magnetograms of a major active region was captured and a large flare observed.

The FDP instrument was assembled and aligned in the Tucson office. Solar images using the chromospheric spectrum lines 656 H I and 1083 nm He I were obtained using a roof-top light feed. Before the FDP can be installed on the SOLIS mount, some work on the camera shutters and two beamsplitting optics need to be completed. The nearly identical high-speed guiders for the VSM and FDP are not finished and the FDP is the test bed for completing that task.

Work on the ISS was held up by a need to borrow some common equipment from it for use on the VSM. The ISS is now back in service, undergoing laboratory tests and calibration before starting a regular series of observations.

The major SOLIS effort in FY 2004 will be to transition SOLIS from initial to regular operations following its installation on Kitt Peak. The FY 2004 budget for operating SOLIS is less than what was proposed and needed to realize the full potential of SOLIS. Proposals to external agencies have been prepared and submitted in an effort to ensure that SOLIS meets the expectations of the user community. If the operating difficulties are solved, we plan to respond to a request by the NRC ten-year plan, "Astronomy and Astro-physics in the New Millennium," with a proposal to build two additional SOLIS units for placement at distant longitudes to form a SOLIS network.

#### **5 NSO OPERATIONS AND UPGRADES**

The advent of solar adaptive optics and its routine use at the Dunn Solar Telescope, as well as the increased use of IR detectors at the McMath-Pierce Solar Telescope and Evans Solar Facility, mark the major changes in NSO operations. The NSO telescope upgrade and instrument development program is guided by the scientific and technical imperatives for developing a new Advanced Technology Solar Telescope. Telescope and instrument upgrades and operations are reviewed and supported on the basis that they serve as necessary preludes to the ATST initiative while concurrently serving the needs of the scientific community. Details of the scientific and technical operations can be found at *http://www.nso.edu*. Brief summaries of the primary projects and operational changes are provided in this section.

#### 5.1 GONG

The Global Oscillation Network Group (GONG) is an international, community-based program designed to conduct a detailed study of the internal structure and dynamics of the Sun, by measuring acoustic 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 processing system to support the coordinated analysis of these data, and a data management system to archive and distribute the data products. GONG data are considered to be in public domain and available to anyone.

A Scientific Advisory Committee, consisting of Sarbani Basu (Yale), Peter Gilman (HAO), Robert Noyes (Harvard-Smithsonian CfA), Philip Scherrer (Stanford), Mike Thompson (Imperial College, London), Alan Title (Lockheed-Martin), Juri Toomre (U. Colorado/Chair), and Roger Ulrich (UCLA), continues to provide overall scientific guidance to the program. In addition, a Data Management and Analysis Center Users' Committee, consisting of Thierry Appourchaux (ESA/ESTEC), Sarbani Basu (Yale), Doug Braun (Northwest Research Associates), Sylvain Korzennik (Harvard-Smithsonian CfA), Ed Rhodes (USC), Philip Stark (UC-Berkeley), and Jesper Schou (Stanford/Chair), provides community input to this critical part of the program.

The GONG stations are hosted by and operate in close collaboration with major international astronomical facilities: NJIT/BBSO in California, HAO's site on Mauna Loa in Hawaii, the IPS Radio and Space Services' Learmonth Solar Observatory in Western Australia, the Physical Research Laboratory's Udaipur Solar Observatory in India, the Instituto de Astrofísica de Canarias' Observatorio del Teide on Tenerife in the Canary Islands, and CTIO in Chile.

GONG continues its evolution from a limited-term project to an NSO flagship program. The site and instrument operations team faces the challenges of aging components, but can also look forward to the opportunities of increased communications bandwidth, which should result in near real-time data verification and diagnostics, better performance, new science, and eventually near-real-time data transfer. Data processing operations in Tucson continue to become more automated and efficient with the implementation of multi-CPU servers, shared resources, and process-controlled pipelines.

The Tucson-based operations staff maintains daily contact with the automatically operating site instruments, monitoring the state of the instruments. Each of the network instruments generates a 200-parameter database, which is transmitted to the Tucson headquarters once a day, for 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 a quick response is required, the network operations "on call" duty responder can be readily accessed via phone, fax, or e-mail. Our collaborators at the host observatories also monitor the instruments locally.

The Data Management and Analysis Center (DMAC) completed the reduction of the raw data from GONG's eighth year of operation: Eight, 36-day-long, GONG months (numbers 71-78) with an average fill factor of 0.82. Data reduction activities over the past year included the identification of mode frequencies from the 108-day-long time series centered on GONG-months 68-77. The data from these and other processing steps continue to be 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, where Internet transfers satisfy most data distributions. During the past year, GONG has transitioned to a completely open data access policy. 1.1 Terabytes of data were distributed in response to 127 data requests.

The instruments collect  $1024 \times 1024$  images, and the data are returned to Tucson to be calibrated and merged. Once merged, the data are processed, maintaining the same  $\ell$  coverage ( $\ell < 200$ ) and producing the same data products as previously for global helioseismology. In order to exploit the full scientific potential of the GONG+ data, the program has implemented a high-performance data handling system and processing pipeline to focus on high- $\ell$  global *p*-mode processing and local helioseismology methods, such as ring diagrams, time-distance, and holography. Results are highlighted in the Science Sec. 3.3.

#### 5.2 ISOON

ISOON (the Improved Solar Observing Optical Network) was completed through prototype demonstration in the summer of 2002 and has now completed more than a year of full-time operation at NSO/Sacramento Peak. Originally, the system was to be deployed at three sites worldwide, but when the program was cancelled as an operational network by the USAF, ownership was transferred to the Air Force Research Laboratory at NSO/Sacramento Peak, where it continues to be used for research and limited support to space weather forecasting. ISOON represents a class of instrumentation intermediate to patrol telescopes and major solar telescope facilities, and can be dedicated to interests of a synoptic nature, especially those involving transient activity such as flares, prominence eruptions, Moreton waves, and active region evolution. Its ability to operate from a remote terminal using an Internet connection was demonstrated in April 2003.

ISOON is a semi-autonomous system that provides imaging in H-alpha, continuum, and line-of-sight magnetic fields. It features a 25-cm aperture evacuated polar-axis refractor, fused silica optics, high-precision 12-bit photometry, registered images with constant magnification and orientation, and 0.1 Å tunable filter system. Both full-disk and high-resolution formats are available. Helium 10830 images will be available beginning in late 2003. ISOON analysis software includes a library of functions for manipulating still images and movies, coordinate overlays, radial average subtractions, automatic flare patrol, automatic sunspot areas, locations, and counts; there are numerous other software functions, which include point and click for zoom, 3-day and 30-day on-line databases, intensity measurement tools.

Further information as well as real time images and movies are available at *http://www.sunspot.noao.edu/sunspot/latest solar images.html*.

#### 5.3 Digital Library and Virtual Solar Observatory

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic data sets over the Internet to the research community. Since the inception of the Digital Library in May 1998, close to 700,000 science data files have been distributed to about 21,000 unique computers. These figures exclude any NSO or NOAO staff members.

NSO has recently installed a new data server for its Web pages and data archives. This server currently has 8 Terabytes of disk space, and has allowed NSO to retire the obsolete and small-capacity robotic CD-ROM jukebox for data storage. The new server will eventually be equipped with 16 Terabytes of on-line disc storage, sufficient to hold about 7 years of SOLIS data as well as the current Digital Library. Currently, the Digital Library holds the entire set of daily solar images from the KPVT, FTS data, a portion of the Sacramento Peak spectroheliograms, and the first SOLIS magnetograms.

In order to leverage further the substantial national investment in solar physics, NSO is participating in the development of a Virtual Solar Observatory (VSO), the European Grid of Solar Observations (EGSO), and the Collaborative Sun-Earth Connection (CoSEC). The VSO will initially comprise a collaborative distributed solar data archive and analysis system with access through the WWW. The system is scheduled to be released for public use as a beta version in December 2003. The overarching goal is to facilitate correlative solar physics studies using disparate and distributed data sets. Necessary related objectives are to improve the state of data archiving in the solar physics community; to develop systems, both technical and managerial, to adaptively include existing data sets, thereby providing a simple and easy path for the addition of new sets; and eventually to provide analysis tools to facilitate data mining and content-based data searches. None of this will be possible without community support and participation. Thus, the solar physics community is actively involved in the planning and management of the VSO. For further information, see *http://vso.nso.edu/*.

#### 5.4 Kitt Peak

#### 5.4.1 NSO Array Camera (NAC)

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 microns. NSO has focused its in-house instrumentation program on the 1-5-micron region. (The McMath-Pierce also carries out observations in the important 12-micron region through collaboration with NASA's Goddard Space Flight Center.) The NSO Array Camera (NAC) project is aimed at providing a large-format, user-friendly facility camera for the McMath-Pierce telescope to be used for imaging, spectroscopy and spectropolarimetry.

The NAC project will use a  $1 \text{ K} \times 1 \text{ K}$  Aladdin InSb array. These arrays have been developed with a significant investment by NOAO, and have low read-noise and high quantum efficiency. The NAC camera will be a significant improvement over the current NSO infrared cameras, more than doubling the collecting area of all the NSO IR cameras used to date.

The NAC project has identified a particular Aladdin-III array for use. A camera controller designed and built at Mauna Kea Infrared (MKIR) is entering its final testing phase and is expected to undergo acceptance testing before the end of 2003. A simplified closed-cycle cooled dewar has been contracted to MKIR to house the array. The dewar has been designed and will enter the construction phase in late 2003, and a relatively rapid production schedule is expected. A list of required cold filters has been generated and will be ordered, and the polarimeter analysis optics used with the NSO NIM camera are being tested for use with NAC.

Implementing and demonstrating the scientific value of a fast, large-format infrared camera is an important component of NSO's preparation for the IR-capable ATST. The initial operation of a large-format, advanced IR instrument at the McMath-Pierce solar telescope facility will offer the most advanced research capability in the mid-IR for solar physics in the world today.

#### 5.4.2 Seeing Improvement

Tests of potential improvements to the telescope seeing have been conducted during the last several years, including fans blowing air across the image-forming mirror, which is heated by the incoming sunlight. The wavefront sensor in the adaptive optics system has also revealed other sources of telescope seeing such as the interface between the telescope and the observing room. Appropriate changes have been made to improve the internal seeing. We do not expect to make further improvements unless the wavefront sensor indicates sources of internal seeing that could be removed.

#### 5.4.3 Adaptive Optics

The infrared adaptive optics project at the McMath-Pierce telescope is nearing completion. During FY 2003, the prototype adaptive optics system was available for scientific use on a shared-risk basis. During the second half of FY 2003, the prototype started its transition into a user system. The prototype optics were replaced with a new optical arrangement that delivers improved image quality over an increased field of view. Furthermore, a scanning unit has been added to precisely move the solar image across the spectrograph slit. An observing manual documents the calibration and operation of the AO system. Finally, in collaboration with Penn State University, a proposal has been submitted to the NSF to design and build a modern, all-reflective integral field unit for infrared spectroscopy of AO-corrected solar images. Most infrared observing runs now request the adaptive optics system. Full documentation as well as the source code for all of the software are available on the Web. The success of this low-cost approach is also illustrated by the fact that solar research groups in Switzerland and India received full funding during 2003 to duplicate the system.

During FY 2004, the conversion to a user system will be completed by upgrading the few remaining components that limit the full field of view. The main limitation of the current system is its deformable mirror. Upgrade options will be investigated during FY 2004. Initial observations of Mercury using the tip-tilt system have been successful. If external funding becomes available, the existing AO system will be duplicated with a few modifications to allow AO-corrected observations of Mercury, which is of high interest to future US and European space missions.

#### 5.4.4 McMath-Pierce Telescope Control System

A new telescope control system (TCS) is needed to ensure that the McMath-Pierce facility remains competitive and maintainable. It is expected that the whole TCS will be based on commercial components that will be integrated by a vendor. During FY 2003, we investigated funding possibilities and the efforts that would be involved for a new TCS. The total cost is beyond the amounts available for telescope upgrades internally, so we will keep looking for external funding options while accumulating internal funds to that end. Cost estimates will also be refined and kept up-to-date until funding becomes available.

#### 5.4.5 East Auxiliary Telescope Upgrade

The field-widening optics and CCD detector for the East Auxiliary telescope were assembled into their operational configuration during FY 2003. A series of tests were performed to determine the limiting sensitivity of the overall system. This was determined to be approximately 18.5 magnitudes, somewhat less than the expected 19<sup>th</sup> magnitude limit. Performance was degraded by scattered light that was evident at long

exposures, apparently resulting from skylight scattered from the mirror optics into the CCD detector. Efforts to baffle this scattered light were unsuccessful. Software for the detection and orbit computation of asteroids was implemented successfully. In view of the fact that the limiting magnitude of the system falls short of the 20-21 magnitude range needed for near-Earth object (NEO) follow-up observations, asteroid researchers were consulted to suggest best uses for the East Auxiliary system. Photometry and spectra of NEOs are thought to be useful. In accordance with that objective, a filter wheel containing standard UBVRI filters for photometry and a grism for spectroscopy were installed. The system is considered to be operational at this point.

## 5.5 Sacramento Peak

## 5.5.1 Advanced Stokes Polarimeter (ASP) Upgrade

The Advanced Stokes Polarimeter was developed by the High Altitude Observatory in collaboration with NSO. Plans to upgrade the ASP include a new diffraction-limited spectro-polarimeter (DLSP) that will permit different image scales, from high-resolution (at the diffraction limit of the Dunn Solar Telescope (DST)) to lower resolution with a larger field-of-view. This project consists of two phases: Phase 1 integrates the DLSP with the low-order AO system and existing CCD hardware on Port 4. Using the existing ASP modulation and demodulation unit, Phase 1 will be used to observe Stokes profiles with reasonable spatial resolution (0.3 arcsec); Phase 2 integrates the DLSP on Port 2 with the high-order AO system and new CCD hardware. A new modulation and demodulation package will be included in order to make the instrument stand alone. With the new CCD hardware, the spatial resolution would be equal to that of the DST.

Phase I of the DLSP project saw first light on 13 March 2002. The instrument was tested at the DST using the low-order adaptive optics and the ASP control system. The initial results showed that the performance of the instrument in the high-resolution mode is better or comparable to that of the ASP.

Phase 2 of this project is nearing completion. During FY 2003, the new modulation and demodulation package was built. A new calibration unit has been installed at the Port 2 of the DST. The new CCD has also been installed and performance-tested with exciting and encouraging initial results. The DLSP is expected to become a user instrument during the spring of 2004.

## 5.5.2 CCD Upgrade

The primary goal of this upgrade is to provide a reliable and stable image-capture system for the DST. Additional benefits include providing interchangeable camera-computer configurations on a day-to-day basis, and easing the required maintenance effort.

The new configuration now consists of a) seven SUN Blade 100's running the Solaris OS; b) a 500 GB Sun Fibre Channel SAN; c) a DLT tape library with 4 DLT 8000's, 30 cartridge capacity; d) all required interconnect hardware; and e) off-table media-transfer stations for transfer of data from DLT to media of choice.

The hardware installation has been completed and software development is nearing completion. We hope to switch over to the new acquisition system in January 2004.

## 5.5.3 IR Camera

NSO and the University of Hawaii Institute for Astronomy agreed to collaborate on the development and scientific use of infrared camera systems. Specifically, this refers to the joint use of the  $256 \times 256$  TCM2620-based IR camera, capable of IR imaging up to 5 microns, and the  $256 \times 256$  NICMOS IR camera used mainly

for polarimetry for wavelengths between 1-2 microns. The goal of this collaboration is to maximize the scientific output from these devices and to support ATST technology development with SOLAR-C, as described in the ATST design and development proposal.

The existing TCM2620 engineering-grade array was recently replaced by a scientific focal-plane array. The camera is now up and running and the new Rockwell array is performing as advertised. The camera has been moved to Haleakala for trial runs and ATST-related research.

## 5.5.4 Dual Fabry-Perot (FP)Filter

A new, narrow Fabry-Perot etalon was ordered and purchased from JDS Uniphase. Two RS-232 software upgrade packages to control the z-modulation were also purchased.

Further software and hardware support and upgrades for the dual Etalon system have been put on hold until other projects are completed and more resources become available.

## 6 EDUCATIONAL AND PUBLIC OUTREACH

NSO has a comprehensive public affairs and educational outreach plan that includes public programs, media information, elements of distance learning (Internet) education, K-12 education, undergraduate and graduate research, teacher research, and research-to-classroom experiences. Scientists at each site have responsibility for the local educational and public outreach program, with additional support provided by other members of the scientific and support staff and, during the summer, by resident students. In FY 2003, Dave Dooling joined the NSO staff to conduct public relations and outreach as part of the ATST program. He is planning and coordinating the ATST educational and public outreach (EPO) efforts with that of the NSO and other ATST partners.

## 6.1 Educational Outreach

## 6.1.1 Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET)

Over 700 announcements about the Summer 2003 Research Experiences for Undergraduates Program at NSO were sent to astronomy, physics, engineering, mathematics, and natural science departments throughout the US and Puerto Rico. An announcement about the NSO Summer 2003 Research Experience for Teachers (RET) Program was widely distributed electronically via the National Astronomy List Serves, Arizona Physics Teachers List Serves and the Arizona Science and Math Education Center; announcements were also sent to schools districts throughout New Mexico and in Tucson. The NSO 2003 Summer Outreach Program supported 8 undergraduates and 3 high school teachers under the NSF-funded REU and RET programs, respectively; 2 undergraduate research assistants under NSO graduate summer program.

## 6.1.2 Teacher Leaders in Research-Based Science Education (TLRBSE)

Christoph Keller and Claude Plymate worked with the NOAO Teacher Leaders in Research-Based Science Education program to develop a long-term solar project for teacher participants. Approximately 10 of the 18 summer 2003 TLRBSE participants spent three days at the McMath-Pierce Solar Telescope, using the infrared spectrograph to observe selected IR spectral lines to measure and map magnetic fields around existing sunspots. On 01 March, 300 flyers about the Researching Active Solar Longitudes (RASL) Project were distributed at the 37th Annual High School Physics Teachers Day at Occidental College in Los Angeles. The RASL Project is a high-school level educational/research module (developed within the NSO Research Experience for Teachers (RET) and NOAO Research-Based Science Education (RBSE) programs) that improves computer and analytical skills and contributes new scientific results to solar astronomy and physics. The RASL Project is being advertised nationwide in an effort to recruit teachers to participate in the project.

## 6.1.3 Project ASTRO

NSO hosted an annual Project ASTRO Teacher Conference at the NSO/Sac Peak Visitor's Center, 01-02 Nov., with more than 20 teachers attending. Throughout the year, Caroline Barban continued to work with students and teachers at Sewell Elementary School in Tucson as part of Project ASTRO.

## 6.1.4 Further Undergraduate and Graduate Education

NSO continues with its strong commitment to supporting graduate education and attracting students to solar physics research. New Jersey Institute of Technology (NJIT) graduate student Klaus Hartkorn did most of his thesis work at NSO under the supervision of Thomas Rimmele and received his PhD in May 2003. His thesis was on high-resolution studies with the Dunn Solar Telescope and adaptive optics. Dr. Rimmele is also advising a second PhD student, Jose Marino, jointly sponsored by NSO and NJIT, and whose thesis is on developing techniques for using the AO wavefront sensor to obtain the instantaneous point spread functions of AO-corrected images so they can be fully restored. Supervised by Dr. K. S. "Bala" Balasubramaniam, David Byers from Utah State University is working on a PhD, assessing methods of predicting solar activity based on surface flows. Michael Eydenberg, also supervised by Bala, completed his Masters thesis at the New Mexico Institute of Mining and Technology on the inversion of Stokes profiles using principal component analysis.

Matt Penn worked with University of Arizona undergraduate students Ali Schmidt and Jill Gerke on ATSTrelated projects. Ali's project, "Physical Models of ATST Sky Brightness Monitor (SBM) Variation," was for her Astronomy 499 independent study class. Jill worked with Dr. Penn on analyzing ATST SBM data. A coauthored paper has been drafted and is scheduled for submission to *Solar Physics*. In April, NSO announced a Utah State University (USU) Space Dynamics Laboratory/NSO "Tomorrow Fellowship" for graduate research in solar physics. The fellowship is intended for research in optical solar astrophysics to be performed jointly at USU in Logan, Utah and at NSO/Sacramento Peak.

Han Uitenbroek and Dooling staffed an exhibit on NSO at the New Mexico Tech career fair in Socorro on 30 January. The exhibit included a new poster that depicted scientific and engineering challenges in exploring the Sun. On 29 April, Mark Giampapa gave a lecture on "Solar and Stellar Activity" to a University of Arizona undergraduate class(ASTR 296 – Research Topics in Astrophysics) at the invitation of Associate Professor Jill Bechtold, course instructor. On 06 May, a group of students from the University of Redlands visited NSO/Tucson. The students were part of an innovative and experimental course designed by Prof. T. Nordgren in which students travel to several astronomical institutions to learn about the modern scientific process from real astronomers in their place of work.

## 6.1.5 Other Educational Outreach

Jackie Diehl and two previous RETs, Demetri Fenzi and Joey Rogers, staffed NSO's first-ever exhibit at the National Science Teacher's Association national convention in Philadelphia, 26-31 March. More than 1,000 teachers received literature on the Advanced Technology Solar Telescope, NSO, and NSO educational activities. Ramona Elrod, Lou Ann Gregory, and Dave Dooling represented NSO/SP at the annual meeting of the Southwestern Consortium of Observatories for Public Education (SCOPE), 14-15 November, at the McDonald Observatory, Fort Davis, TX. Diehl and Dooling represented NSO/SP at "Visions and Voices: Educational Leadership in the Research Center Environment," an NSF-sponsored workshop held on 26-28 October in Santa Cruz.

Throughout the year, scientific staff at both sites gave talks at local elementary schools and organized star parties for students, parents and teachers. NSO officials from Sac Peak and Tucson also assisted with city and regional science fairs in their areas.

Ray Smartt (NSO Emeritus Astronomer in residence at Malabula, New South Wales, Australia) accompanied a group of students (11 astrophysics majors) and faculty from Williams College on a trip to Ceduna, South Australia, for the total eclipse on 04 December. On 10 April, K. S. Balasubramaniam was the guest on an hour-long, call-in television program organized by the El Paso Independent School District. NSO scientific staff supported a number of activities at K-12 schools or for youth groups, such as scouts attending a special program on Kitt Peak involving the Space Weather Center exhibit and observing the Sun with a 16-inch telescope and H-alpha filter, and talks in schools.

#### 6.2 Public Outreach

#### 6.2.1. Sunspot Visitor Center

The Sunspot Visitor Center continued development work on the heliostat viewer, which has been built up from the original helioseismology telescope that operated at the South Pole in the 1980s. It is located outside the Visitor Center and projects an image into the building. An optical system in the building splits the beam at a mirror with a slit. Light reflected from the mirror is projected onto a rear screen to provide a white light image of the Sun. Light passing through the slit is reflected from a dispersion grating to project a spectrum on another rear screen and reveal the major solar absorption lines. Backlit display panels explain each image. Software issues with the tracking mirrors have delayed the heliostat's operation to late 2003.

Preparations also were made to exhibit an antique solar telescope. The 12-inch refractor was designed and built by American astronomer Lewis M. Rutherfurd in the mid-to-late 19th century. The Visitor Center also added a new exhibit banner on Ancient Observatories of the Southwest, and partnered with the Alamogordo Public School System and the Space Museum and Hall of Fame on a IDEAS grant proposal to have students build VR and museum replicas of stone cairns, located in the Sacramento Mountains and used by early American Indians as observatories.

During the year, the Visitor Center hosted approximately 15,000 visitors. Another 5,000 to 7,500 toured the NSO grounds (open sunrise to sunset) without entering the Visitor's Center. Public lectures and guided tours were held daily at 2 pm during the summer months when RET and REU interns were available. More than 400 invitations to visit the Center were mailed to New Mexico and West Texas (El Paso) schools and youth groups (scouts, Girls Inc., etc.). These helped increase field trips to the Visitor Center and led to interest in sleep-in trips that are being planned for Spring 2004. Among special facility tours conducted for the public, NSO hosted groups from the University of Texas at El Paso; Texas Tech University; New Mexico Tech University; Johns Hopkins University; New Mexico State University; and Camp Enchantment, a camp for children with cancer sponsored by the New Mexico chapter of the American Cancer Society.

#### 6.2.2 Other Public Outreach

NSO Director Steve Keil met with Daniel Dwyer, Vice Provost for Research at New Mexico State University, on 20 November, to discuss the ATST; and on 12 December, Keil briefed New Mexico Congressman Steve Pearce and the Alamogordo Chamber of Commerce on NSO Structure and Plans, including ATST. Sunspot staffed an exhibit on NSO at the Lincoln National Forest centennial celebration held by the U.S. Forest Service, 13 November, in Alamogordo. The exhibit included a new poster that depicted the history (1947-present) of NSO at Sacramento Peak, and bookmarks that included a map to guide visitors to Sunspot. Staff

participated in Astronomy Day events and the Alamogordo Earth Day Fair, gave talks on adaptive optics and IR solar imaging to astronomy clubs, and supported local star parties.

## 6.2.3 External Coordination

On 16-20 June, 17 NSO staff attended the 34th Solar Physics Division (SPD) meeting of the American Astronomical Society in Laurel, MD. Sixteen poster papers and five talks (one of which was the invited Hale Prize Lecture) were presented by NSO staff and resident partners. One of the poster papers, on "Chirality of Chromospheric Filaments," involved former Research Experience for Teachers (RET-2001) participant J. W. Rogers of Cloudcroft Elementary and Middle Schools. NSO was an exhibitor at the SPD meeting, with a booth featuring poster displays and handouts on the Observatory's major projects and initiatives. NSO also posted more than 80 photos from the meeting for use by NSO and SPD. Extensive effort was expended in preparation for NSO's presence in the NSF's public meeting on *The Universe from the Ground Up*, which was held in October.

## 6.3 Media and Public Information

## 6.3.1 Press Releases and Image Releases

The major news event for NSO during the year was the announcement of a breakthrough in high-order adaptive optics at the Dunn Solar Telescope. The news was released at the AAS Solar Physics Division meeting in Laurel, MD, in late May. News products included an illustrated 4-page fact sheet and a companion Web story, as well as a press conference. The Web story included more than 20 high-resolution, print-quality images. Simultaneous solar flares observed by ISOON on 31 October was the other event that generated extensive national coverage. The original story was posted to the Web, then forwarded to the *Albuquerque Journal*. An AP version was carried by CNN, MSNBC, and other news outlets. Three press releases were issued in May on GONG activities leading up to, and the network's observations of, the 22 May transit of Mercury.

Curt Suplee, a freelance writer on assignment for *National Geographic*, visited Sunspot on 06-07 December for interviews on an article on recent solar science developments and plans for future work. He talked with several of the Sac Peak scientific staff, then went to NSO/Tucson for additional interviews. Production of the article is expected in 2004.

## 6.3.2 Special Information Products

The major product developed during the year is a 24-page color booklet describing the mission, science, and technology of the Advanced Technology Solar Telescope (ATST). The target audience includes the news media, AURA and NSF program managers, and elected officials. The booklet is written for a science attentive audience and is similar in style to previous NASA booklets describing space missions. It will be printed in early FY 2004 for distribution early in CY 2004.

During the year, NSO designed and published two trifold brochures for public and professional distribution. The first highlighted the ATST project and provides basic details on the mission, design, and science questions. It has been reprinted (the second included small updates on the design). The other trifold was focused on tourism at NSO/Sunspot and included highlights of what visitors can see and do, plus a detailed map of the Sunspot Highway. More than 5,000 copies have been distributed and a reprint is planned in FY 2004. A  $1 \times 8$ -inch bookmark version of the map was printed (10,000 units) for distribution to schools.

#### PRESS RELEASES ISSUED IN FY 2003

- June 18, 2003: "Smoothing Out the Wrinkles in Our View of the Sun" (Latest News on the Solar Adaptive Optics Project) <u>http://www.nso.edu/nsosp/ao/</u>
- May 28, 2003: "Sun Remains Active Late in 11-Year Cycle" <u>http://www.nso.edu/press/isoon\_flare/</u>
- Mercury Transit:
  - May 22, 2003: "GONG Observes the Transit of Mercury" (composite and summary information) <u>http://www.nso.edu/press/transit.html</u>
  - May 8, 2003: "GONG Network Records Transit of Mercury, Ready for Venus" <u>http://www.nso.edu/press/post\_merc\_transit.html</u>
  - May 5, 2003: "Modern Solar Telescope Network's View of Mercury Passage Will Help Students Use Web to Recall Historical Era" <u>http://www.nso.edu/press/mercury\_transit.html</u>
- March 31, 2003: RAS Press Notice PN03-10: "Sunquakes Reveal the Solar Furnace" <u>RAS PN</u> <u>03/10 Sunquakes Reveal the Solar Furnace</u>

#### 6.3.3 Web-Based Outreach

The NSO WWW site (*http://www.nso.edu*) contains several public outreach areas. These include a live solar image that is updated once per minute so the public (and the scientific community) can see how the Sun is behaving in H-alpha. These images allow the observer to quickly assess the state of solar activity. Virtual tours of the NSO sites, including telescope descriptions, are available. There is an interactive solar tutorial that provides information about the Sun and its processes. There is also an "Ask Mr. Sunspot" area where questions can be asked about the Sun and astronomy in general. Answers are posted on the Web and indexed so visitors can easily look at past answers by subject. A data archive is also available. While intended for scientific research, it is also accessible by the general public and to students working on solar projects. During the past year, the NSO Web pages have been redesigned extensively to be more informative and user-friendly.

#### 6.3.4 Image Requests

In addition to providing images to accompany press and other media releases, NSO provided annotated ATST drawings for use by two book authors expressing interest in including ATST materials in upcoming projects. There are plans for developing an NSO image archive and search system to provide quick access to high-resolution images on line.

## **APPENDIX A**

## **OBSERVING AND USER STATISTICS**

In the 12 months ending 30 September 2003, 67 observing programs, 6 of which were thesis programs, were carried out at NSO. Associated with these programs were 68 scientists from 39 US and foreign institutions.

NSO Observing Programs by Type (US vs Foreign)				
12 Months Ending Sept-2003	Nbr	% Total		
Programs (US)	52	78%		
Programs (non-US)	9	13%		
Thesis (US)	3	4%		
Thesis (non-US)	3	4%		
Total Number of Unique Science Pro	ojects* 67	100%		

Users of NSO Facilities by Category					
		Vis	NSO/NOAO Staff		
	US	Non-US	Total	% Total	
PhDs	47	21	68	80%	18
Graduate Students	4	6	10	12%	-
Undergraduate Students	6	0	6	7%	-
Other (Research Tech.)	0	1	1	1%	9
Total Users	57	28	85	100%	27

\*Includes observing programs conducted by NSO/NOAO staff scientists.

Institutions Represented by Visiting Users**						
	US	Non-US	Total	% Total		
Academic	15	9	24	62%		
Non-Academic	10	5	15	38%		
Total Academic & Non-Academic	25	14	39	100%		

\*\*Note: Total number of institutions represented by users do not include departments or divisions within an institution as separate entities (e.g., US Air Force and NASA are each counted as one institution even though several different sites/bases/centers are separately listed in the data base.

Number of Users by Nationality						
Canada	3	Italy	2			
Chile	2	Japan	4			
England	1	Mexico	1			
France	1	Norway	1			
Germany	3	Switzerland	6			
Ireland	4	United States	84			

#### INSTITUTIONS REPRESENTED BY USERS

#### **US Institutions (25)**

American Institute of Physics NASA/Langley Research Center Cambridge Research and Instrumentation National Oceanic & Atmospheric Administration College of William & Mary, VA New Jersey Institute of Technolgy/Big Bear Solar Observatory Connecticut College South Carolina State University Dickinson College Southern Illinois University at Edwardsville East Carolina University, NC Southwest Research Institute Edinboro University, PA

#### Foreign Institutions (14)

University of Calgary University of Oslo University of Waterloo ETH, Zürich University of Cologne European Southern Observatory Max-Planck Institute of Astrophysics University of Arizona Haverford College University of California, Berkeley Helio Research University of Colorado High Altitude Observatory, NCAR, Boulder University of Hawaii, IFA Jet Propulsion Lab, Pasadena, CA University of Wisconsin, Madison Lockheed Martin Solar & Astrophysics Lab US Air Force, Los Angeles AFB NASA/Goddard Space Flight Center (NASA/GSFC) US Air Force/Philips Lab (USAF/PL/GSS)

Mullard Space Science Laboratory Queens University Observatoire de Pic-du-Midi University of Tokyo, NAO INAF - Arcetri Astrophysical Observatory Universidad de Monterrey National Astronomical Observatory of Japan

## FY 2003 USER STATISTICS - TELESCOPE USAGE AND PERFORMANCE DATA

In the fiscal year ending 30 September 2003, 39.0% of the total available telescope hours at NSO/Sacramento Peak and NSO/Kitt Peak went to the observing programs of visiting principal investigators; 15.9% were devoted to those of NSO scientists. Scheduled maintenance (including instrument tests, engineering, and equipment changes) accounted for 4.5% of total allotted telescope hours.

Total "downtime" (hours lost to weather and equipment problems) for NSO telescopes was 40.7%. Almost all of these lost observing hours were due to bad weather (32.4%), with 8.3% lost to equipment problems.

NSO TELESCOPES Percent Distribution of Telescope Hours (Scheduled vs. Downtime) 01 October 2002 - 30 September 2003						
		% Hours	Used By:	% Hours	s Lost To:	% Hrs. Lost To:
Telescope	Hours Available	Visitors*	Staff	Weather	Equipment	Scheduled Maintenance
Dunn Solar Telescope/SP	3,634.0	22.0%	19.1%	31.8%	4.9%	22.2%
McMath-Pierce	4,971.0	26.1%	36.1%	25.6%	12.2%	0.0%
KP Vacuum	2,270.0	43.1%	29.6%	26.3%	1.1%	0.0%
FTS Lab	1,229.3	48.0%	0.0%	0.7%	41.1%	10.2%
Evans Facility	2,092.8	32.5%	7.2%	45.9%	14.2%	0.2%
Hilltop Dome	6,666.0	57.0%	0.0%	41.4%	1.7%	0.0%
All Telescopes	20,863.1	39.0%	15.9%	32.4%	8.3%	4.5%

\*Includes synoptic programs for which all data are made available immediately to the public and scientific community at large.



## FY 2003 USER STATISTICS – ARCHIVES/DATA BASES

#### NSO/SACRAMENTO PEAK

Combined User Demographics (NSO/SP)					
Demographic Group	Requests	Traffic			
U.S. Science (.gov, .edu, .mil)	8.2%	8.2%			
Other U.S. (.com, .net, misc.)	67.8%	69.7%			
Foreign	20.9%	18.9%			
Unresolved	3.1%	3.2%			

#### **FTP** Archive Statistics

There were 536,780 successful user requests serving 5,780 distinct files to 35,738 distinct hosts. A total of 78.023 Gbytes were served averaging 228.902 Mbytes per day.

FTP User Demographics (NSO/SP)						
Demographic Group	Requests	Traffic				
U.S. Science (.gov, .edu, .mil)	4.4%	7.5%				
Other U.S. (.com, .net, misc.)	75.7%	74.2%				
Foreign	18.7%	15.3%				
Unresolved	1.2%	3.0%				

FTP Products (NSO/SP)						
Demographic Group	Requests	Traffic				
Realtime Images	52.2%	61.4%				
Corona Maps	43.0%	12.6%				
Sunspot Numbers	1.2%	0.2%				
Staff Outgoing	2.9%	22.2%				
Other	0.7%	3.6%				

## World Wide Web Statistics

There were 3,349,548 successful user requests serving 26,511 distinct files to 206,340 distinct hosts. A total of 60.082 Gbytes were served averaging 168.560 Mbytes per day.

WWW User Demographics (NSO/SP)			
Demographic Group	Requests	Traffic	
U.S. Science (.gov, .edu, .mil)	8.8%	9.2%	
Other U.S. (.com, .net, misc.)	66.5%	63.8%	
Foreign	21.3%	23.6%	
Unresolved	3.4%	3.5%	

WWW Products (NSO/SP)			
Demographic Group	Requests	Traffic	
Realtime Images and Movies	5.9%	8.3%	
Other Images	8.1%	28.6%	
General Icon and Background Images	31.5%	16.8%	
Public Relations Pages	17.7%	10.2%	
Press Releases	2.1%	4.9%	
Telescope Home Pages	6.8%	4.9%	
ISOON	2.1%	0.6%	
Adaptive Optics Pages	0.9%	3.0%	
General Information	11.2%	5.7%	
Staff Pages	1.2%	6.9%	
Other	12.5%	7.8%	

Note: These statistics exclude the internal use of these services from within the NSO/SP Local Area Network. The numbers do not include NSO/Tucson. Historical use trends can be found at *http://www.nso.edu/WEB-REPORTS/trends.html* 

## NSO/TUCSON

- 5,863 FTP users
- 119,044 FTP logins
- 487,173 files downloaded via anonymous FTP
- 672,975 Web page hits (not counting in-line images)
- 3,193,166 Web page hits including in-line images
- Distribution of downloaded data products by number of files:
  - 1. 32% KPVT (magnetograms, synoptic maps, helium images)
  - 2. 20% FTS (spectral atlases, general archive)
  - 3. <1% Sac Peak spectroheliograms (Hα, Calcium K images)
  - 4. 48% GONG (magnetograms, spectra, time series, frequencies)

Note: These statistics exclude the internal use of these services from within the NSO/T Local Area Network. The numbers do not include NSO/SP.

FTP User Demographics (NSO/Tucson)			
Demographic Group	FTP Users	FTP Logins	FTP File Downloads
US Science	15%	40%	61%
US Public	30%	12%	10%
Foreign	28%	39%	22%
Unresolved	26%	10%	7%



## **APPENDIX B**

## FY 2003 PUBLICATIONS October 2002 through September 2003 (Total = 155)

The following is a **partial** list of papers published during FY 2003 by NSO staff, as well as papers resulting from the use of NSO facilities.

Altrock, R. C. 2002, "Long-Term Variation of the Rotation of the Solar Corona," COSPAR, Coll. Series 13, eds. P. C. Martens & D. Cauffman, 337

Altrock, R. C. 2003, "A Study of the Rotation of the Solar Corona," Sol. Phys., 213, 23

Anita, H. M. 2002, "Subsurface magnetic fields from Helioseismology," ed. H. Sawaya-Lacoste, IAU Coll. 188, (ESA) SP-505, 71

Antia, H. M. 2003, "Seismic Studies of Temporal Variations inside the Sun," in Probing the Sun with High Resolutions, eds. S. C. Tripathy & P. Venkatakrishnan (Narosa Publishing House), 13

Antia, H. M., Chitre, S. M., & Thompson, M. J. 2003, "On Variation of the Latitudinal Structure of the Solar Convection Zone," A&A, 399, 329

Arge, C. N., Hildner, E., Pizzo, V. J., & Harvey, J. 2002, "Two Solar Cycles of Non-Increasing Magnetic Flux," J. Geophys. Res., 107, 1319

Ayres, T. R. 2003, "Resolution of the COmosphere Controversy," ASP Conf. Series 286, eds. A. A. Pevtsov & H. Uitenbroek, 431 pp

Balasubramaniam, K. S., Christopoulou, E. B., & Uitenbroek, H. 2003, "Simultaneous Chromospheric and Photospheric Spectropolarimetry of a Sunspot," ASP Conf. Series 286, eds. A. A. Pevtsov & H. Uitenbroek, 227

Balasubramaniam, K. S. & Titus, T. 2003, "High Resolution Imaging Spectroscopy of Sunspots," ASP Conf. Series 286, eds. A. A. Pevtsov & H. Uitenbroek, 259

Ballester, J. L., Oliver, R., & Carbonell, M. 2002, "The Near 160-Day Periodicity in the Photospheric Magnetic Flux," ApJ, 566, 505

Barban, C. & Hill, F. 2003, "Solar Oscillation Parameters: Simultaneous Velocity-Intensity Spectral and Cross-Spectral Fitting," ed. H. Sawaya-Lacoste, (ESA) SP-517, 223

Barban, C., Goupil, M. J., Van't Veer-Menneret, C., Garrido, R., Kupka, F., & Heiter, U. 2003, "New Grids of ATLAS9 Atmospheres: II Limb-Darkening Coefficients for the Stromgren Photometric System for A-F Stars," A&A, 405, 1095

Basu, S. & Antia, H. M. 2003, "Changes in Solar Dynamics from 1995 to 2002," ApJ, 585, 553

Basu, S. & Antia, H. M. 2003, "Temporal Variations in the Rotation Rate in the Solar Interior," ed. H. Sawaya-Lacoste, (ESA) SP-517, 235

Basu, S., & Antia, H. M. 2003, "Temporal Variations of Solar Structure," ed. H. Sawaya-Lacoste, (ESA) SP-517, 231

Basu, S. & Antia, H. M. 2003, "Helioseismic Estimates of Solar Structure and Dynamics," ASP Conf. Series 293, S. C. Keller, & R. M. Cavallo, 250

Basu, S. & Anita, H. M. 2003, "Changes in Solar Dynamics from 1995 to 2002," ApJ, 585, 553

Basu, S. Christensen-Dalsgaard, J., Howe, R., Schou, J., Thompson, M. J., Hill, F., & Komm, R. 2003, "A Comparison of Solar p-Mode Parameters from MDI and GONG: Mode Frequencies and Structure Inversions," ApJ, 591, 432

Basu, S., Simmons, B., & Bogart, R. S. 2003, "Near Surface Sound Speed from Ring Diagrams," ed. H. Sawaya-Lacoste, (ESA) SP-517, 227

Benevolenskaya, E. E., Kosovichev, A. G., Scherrer, P. H., Lemen, J. R., & Slater, G. L. 2002, "Coronal Patterns of Activity from Yohkoh and SOHO/EIT Data," COSPAR Coll. Series 13, eds. P. C. Martens & D. Cauffman, 329

Berger, T. E. & Lites, B. W. 2002, "Weak-Field Magnetogram Calibration Using Advanced Stokes Polarimeter Flux-Density Maps," Sol. Phys. 208, 181

Berger, T. E. & Lites, B. W. 2003, "Weak-Field Magnetogram Calibration Using Advanced Stokes Polarimeter Flux Density Maps. II. SOHO/MDI Full-Disk Mode Calibration," Sol. Phys., 213, 213

Bigazzi, A. & Ruzmaikin, A. A. 2003, "The Magnetic Field in the Convection Zone," ed. H. Sawaya-Lacoste, (ESA) SP-517, 239

Bilenko, I. A. 2002, "Coronal Holes and the Solar Polar Field Reversal," A&A, 396, 657

Braun, A. S., Toomre, J. 2003, "Solar Turbulence and Magnetism Studied Within a Rotating Convective Spherical Shell," ASP Conf. Series 293, eds. S. Turcotte, S. C. Keller, & R.M. Cavallo, 134

Braun, D. C. & Lindsey, C. 2003, "Helioseismic Imaging of the Farside and the Interior," ed. H. Sawaya-Lacoste, (ESA) SP-517, 15

Chitre, S. M. & Anita, H. M. 2003, "Seismic Sun" in Dynamic Sun, ed. B. N. Dwivedi, (Cambridge University Press), 36

Chou, D.-Y. & Serebryanskiy, A. 2002, "Searching for the Signature of the Magnetic Fields at the Base of the Solar Convection Zone with Solar Cycle Variations of p-Mode Travel Time," ApJ, 578: L157

Choudhary, D. P. & Gosain, S. 2003, "Study of Bright Points in the Off-Band Hα Filtergrams of Active Regions," Astron. Nach., 324, 367

Christopoulou, E. B., Skodras, A., Georgakilas, A. A., & Koutchmy, S. 2003, "Wavelet Analysis of Umbral Oscillations," ApJ, 591, 416

Clark, R., Harvey, J., Hill, F., & Toner, C. 2003, "Correcting GONG+ Magnetograms for Instrumental Non-Uniformities," ed. H. Sawaya-Lacoste, (ESA) SP-517, 251

Consolini, G., Berilli, F., Florio, A., Pietropaolo, E., & Smaldone, L. A. 2003, "Information Entropy in Solar Atmospheric Fields. I. Intensity Photospheric Structures," A&A, 402, 1115

Corbard, T., Dikpati, M., Gilman, P. A., & Thompson, M. J. 2002, "Effect of Subsurface Radial Differential Rotation on Flux-Transport Solar Dynamos," ed. A. Wilson, (ESA) SP-508, 75

Corbard, T., Toner, C., Hill, F., Hanna, K. D., Haber, D. A., Hindman, B. W., & Bogart, R. S. 2003, "Ring Diagram Analysis with GONG++," ed. H. Sawaya-Lacoste, (ESA) SP-517, 255

Dalrymple, N. E., Bianda, M., & Wiborg, P. H. 2003, "Fast Flat Fields from Scanning Extended Sources," PASP, 115, 628

Denker, C., Didkovsky, L., Marquette, W. H., Goode, P. R., & Rimmele, T. 2003, "Seeing Characteristic at a Lake-Site Observatory," ASP Conf. Ser. 286, eds. A. A. Pevtsov & H. Uitenbroek, 2

DeRosa, M. L., Gilman, P. A., & Tomre, G. C. 2002, "Solar Multiscale Convection and Rotation Gradients Studied in Shallow Spherical Shells," ApJ, 58, 1356

Didkovsky, L. V., Denker, C., Goode, P. R., Wang, H., & Rimmele, T. R. 2003, "High-Order Adaptive Optical System for Big Bear Solar Observatory," Astron. Nach., 324, 297

Didkovsky, L. V. et al. 2002, "High-Order Adaptive Optical System for Big Bear Solar Observatory," SPIE: Proceedings, 4853, 630

Dorotovic, I., Sobotka, M., Brandt, P. N., & Simon, G. W. 2002, "Evolution of Small-Scale Structures in and around a Large Solar Pore," ed. A.Wilson, (ESA) SP-506, 435

Dulick, M., Bauschlicher, C. W. Jr., Burrows, A., Sharp, C. M., Ram. R. S., & Bernath, P. 2003, "Line Intensities and Molecular Opacities of the FeH F  ${}^{4}\Delta_{i}$  – $X^{4}\Delta_{i}$  Transition," ApJ, 594, 651

Durrant, C. J. & Wilson, P. R. 2003, "Observations and Simulations of the Polar Field Reversals in Cycle 23," Sol. Phys., 214, 23

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Eff-Darwich, A., Korzennik, S. G., Jimenez-Reyes, S. J., & Hernandez, F. P. 2002, "An Upper Limit on the Temporal Variations of the Solar Interior Stratification," ApJ, 580, 574

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Erdélyi, R. 2002, "Effects of the Atmosphere and of Sub-Surface Flows on Solar Oscillation Modes (Invited Review)," ed. A. Wilson, (ESA) SP-506, 869

Fleming, T. A., Giampapa, M. S., & Garza, D., "The Quiescent Corona of VB 10," ApJ, 594, 982

Gaizauskas, V. 2002, "Formation of a Switchback during the Rising Phase of Solar Cycle 21," Sol. Phys., 211, 179-188

Gallagher, P. T., Moon, Y. J., & Wang, H., "Active-Region Monitoring and Flare Forecasting," Sol. Phys., 209, 171

Gandorfer, A. 2002, "Imaging Vector Polarimetry at the 10<sup>-5</sup> Level in the Visible and Ultraviolet Part of the Solar Spectrum," ed. S. Fineschi, SPIE: Proceedings, 4843

Gandorfer, A. 2003, "The Second Solar Spectrum in the UV," ASP Conf. Series, eds. J. Trujillo-Bueno & J. Sanchez Almeida

García, R. A., Eff-Darwich, A., Korzennik, S. G., Couvidat, S., Henney, C. J., & Turck-Chièze, S. 2003, "Analysis of Rotational Frequency Splittings Sensitive to the Rotation Rate of the Solar Core," ed. H. Sawaya-Lacoste, (ESA) SP-517, 271

Gavryuseva, E. & Gavryusev, V. 2002, "Acoustic Power Distribution through Solar Cycle," ed. A. Wilson, (ESA) SP-506, 1057

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## APPENDIX C

#### **ORGANIZATIONAL PARTNERSHIPS**

Through its operation of the majority of US ground-based solar facilities and its ongoing synoptic programs, NSO is clearly important to the solar community. In turn, NSO must closely work with the solar community and provide leadership to strengthen solar research, renew solar facilities and to develop the next generation of solar instrumentation. Some past examples of NSO meeting this responsibility include development of GONG, solar adaptive optics, infrared observing capabilities in collaboration with NOAO, NASA and Michigan State University, and participation in the development of the Advanced Stokes Polarimeter with the High Altitude Observatory (HAO). Table C-1 lists several joint projects and development efforts.

NSO sponsored several community workshops and forged an alliance of 22 institutions to develop a proposal for the design of the Advanced Technology Solar Telescope (ATST) and its instrumentation. NSO will continue to work closely with this group in leading the successful completion of the design and planning for construction of the telescope. An ATST Science Working Group was formed to develop the detailed science requirements for the telescope.

Table C-1. Joint Development Efforts			
Telescope/Instrument/Project	Collaborators		
Advanced Technology Solar Telescope	<ul> <li>HAO, U. Hawaii, U. Chicago, NJIT, Montana State U., Princeton, Harvard/Smithsonian, UC-San Diego, UCLA,</li> <li>U. Colorado, NASA/GSFC, NASA/MSFC, Caltech, Michigan State U. U. Bachester, Stanford, Leokhard Martin, Sauthurat</li> </ul>		
	Research Institute, Colorado Research Associates, Cal State Northridge		
Adaptive Optics	NJIT, Kiepenheuer Institute		
Diffraction-Limited Stokes Polarimeter	НАО		
Synoptic Solar Measurements	USAF, NOAA, NASA		
Fourier Transform Spectrometer	NASA, U. Wisconsin		
Zürich Imaging Polarimeter	ETH-Zürich		
Near Infrared Magnetograph	NASA		
IR Spectrograph	U. Hawaii		
Solar Dual Image Motion Monitor	U. Chicago		

NSO established collaborations with the New Jersey Institute of Technology (NJIT) and the Kiepenheuer Institute of Solar Physics (KIS) to successfully obtain resources from the NSF/MRI program for the development of the high-order solar adaptive optics (AO) system. NSO personnel have been working closely with personnel from NJIT to design, build and test the system, which is essential to ATST development.

NSO and HAO have renewed their partnership to develop the next generation of the Advanced Stokes Polarimeter, the Diffraction-Limited Spectro-Polarimeter (DLSP). Together, they are developing an instrument that will be able to take advantage of the diffraction-limited images delivered by adaptive optics.

SOLIS is being developed by NSO to provide high-quality synoptic data to the community. While an NSO initiative, the SOLIS enterprise was highly endorsed by the solar community in both the NRC Parker Report

and the Decadal Survey. NSO will assume leadership in forging alliances to expand SOLIS to a three-network system.

NSO leads a large consortium of scientists on the GONG program and has taken on the responsibility of upgrading the GONG network to provide data for the recently emerging field of local helioseismology for probing the solar interior near the surface.

NSO and NOAO share expertise in the development, acquisition and implementation of IR technologies for imaging and spectroscopic applications in astrophysics. The NSO received a  $1024 \times 1024$  ALADDIN array at no cost from the NOAO development program to initiate a new and powerful IR camera system for solar astrophysics. NSO and NOAO staff consult on the technical aspects of this project, which serves as an example of the inter-Center cooperation, which AURA management fosters.

Finally, NSO, in coordination with its ATST partners, is undertaking a vigorous expansion of solar outreach programs.

## **Operational Partnerships**

NSO's strategic planning embraces the interdisciplinary nature and dual objectives of solar physics: that it is both basic science and applied research. Likewise, NSO's relationships to its users reflect the diversity and richness of the communities they represent—solar and stellar astronomy, space plasma physics, solar-terrestrial relationships, space weather prediction, terrestrial atmospheric chemistry, and more.

NSO's mission to serve these communities, while remaining a scientific leader in solar physics, is critical because it is unique. NSO's solar telescopes are the largest and best instrumented in the world; NSO is unquestionably the dominant provider of ground-based solar observational facilities in the United States.

In accepting this significant responsibility, NSO has forged partnerships that strengthen its scientific and observational programs while satisfying partner needs. These partnerships range from long-term "residential" relationships to the cooperative development of individual instruments. In return, funding and co-located personnel from the partners permits NSO to operate a wider variety of instruments for longer periods that it could otherwise afford.

## Air Force

The Air Force Research Laboratory (AFRL) maintains a staff of five to six scientists at NSO/Sacramento Peak. The AFRL program emphasizes studies of solar activity and activity prediction techniques, advanced imaging, and development of new instrumentation. Air Force funding is provided for several synoptic programs and for the general operation of Sacramento Peak. AFRL ongoing programs include synoptic observation of coronal emission lines using the Evans Solar Facility coronagraph, observations of chromospheric heating and variability, studies of the Sun as a star, imaging of solar mass ejections with the Solar Mass Ejection Imager (SMEI), and use of the new ISOON flare patrol data to study prominence evolution and filament eruptions.

The Air Force program has provided funding for adaptive optics, development of narrowband filters, procurement of infrared cameras, and CCD cameras. The AF staff collaborates closely with NSO scientists on both science and instrument development. The Air Force Office of Scientific Research has expressed interest in the ATST and plans to maintain the Air Force solar research presence as NSO transitions to ATST operations.

Table C-2. Current NSO Partnerships			
Partner	Program		
Air Force Research Laboratory	Solar Activity Research at NSO/SP; Telescope Operations; Adaptive Optics; Instrument Development; 6 Scientists Stationed at NSO/SP; Daily Coronal Emission Line Measurements; Provides Operational funding: \$400K-Base and Various Amounts for Instrument Development.		
NASA	KPVT Operations; Collaborative Science; SOLIS Development; Instrumentation; 1 Permanent Scientist; 1 Research Fellow at NSO/T; Operational Funding: \$32K for Telescope Operations and Various Amounts for Instrumentation.		
	McMath-Pierce: Support for Operation of the FTS; Upper Atmospheric Research.		
Office of Naval Research	Solar Activity Prediction; Support for KPVT Operations; 1 or 2 Postdocs Per Year.		
NSF Chemistry	FTS Facility Support		

#### NASA

The Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center (GSFC) has cooperated with NSO for over twenty years in operating and developing the Kitt Peak Vacuum Telescope (KPVT) and is extending this effort to SOLIS. GSFC currently has one civil service scientist stationed in Tucson and, through competitive proposals, funds a second scientist and provides additional funding for KPVT operations. NASA obtains daily full-disk magnetograms and spectroheliograms for mission planning and scientific analysis plus rapid access to the KPVT for special observations. Many KPVT instrumentation projects have been partially funded through this cooperation including the current NSO/NASA spectromagnetograph, and current instrumentation funds are being used to procure components of the data and polarization modulation systems for SOLIS. Current research conducted by the NASA-supported staff focuses on use of the He I 1083 nm line as a diagnostic tool for solar mass loss and the association of magnetic features with solar irradiance variation.

A separate NASA proposal provides funding for operating, maintaining, and developing the Fourier Transform Spectrometer at the McMath-Pierce facility in support of upper atmospheric research conducted by scientists at several NASA centers (JPL, Langley, GSFC, and Ames). One full-time instrument observing associate is supported through this task.

#### Office of Naval Research (ONR)

The ONR Ocean, Atmosphere, and Space Science and Technology Department has a continuing interest in solar activity and its effects on naval operations. ONR fosters research in solar activity by means of grants to a few ground-based solar observatories. The data produced by the KPVT and spectromagnetograph has been of unique interest and ONR has supported research work at NSO to utilize this data set for more than a decade. The grants fluctuate in size from year to year and are used for salary and benefits support for young post-doctoral researchers to work in Tucson at a level of one or two per year. Previous researchers include Rudolf Komm, Sidney D'Silva, Yuhong Fan, and John Worden. Currently, Drs. Carl Henney and Roberta Toussaint are supported by an ONR grant.

The ONR grants are of great importance in improving the scientific output of the magnetograph facility on Kitt Peak. Other funding sources and partnerships primarily support operation of the facility but not scientific research. The leverage of the ONR grant allows an in-house research effort that otherwise would not be possible. The main focus of the present grant is improvement of the quality of the synoptic data, research into aspects of the solar magnetic field that have potential predictive capabilities, and development of new data products that test and extend our knowledge of the magnetic drivers of space weather. The focus in a new proposal will be on using new SOLIS data for studies of the vector magnetic field that have heretofore been impossible and on development of a test bench of numerical and physical models that claim predictive capability of solar activity.

## **NSF Chemistry**

The purpose of the laboratory program funded by the NSF Chemistry Division is to provide access to the highresolution Fourier Transform Spectrometer facility at the NSO McMath-Pierce for visiting investigators not directly associated with astronomical research, but rather to the areas of atomic and molecular laboratory spectroscopy.

Part of the research funded by this program is indirectly involved with astrophysical research in that it provides important spectroscopic information, such as line assignments and atomic or molecular constants, derived from spectra of atoms or molecules generated under laboratory conditions. This information assists astronomers in establishing the presence of these species in sunspots, stellar atmospheres, and interstellar clouds.

The largest portion of the research is primarily devoted to problems of physical and chemical interests. For example, an ongoing study by Lawler at the University of Wisconsin involves measuring the branching ratios of lanthanide atomic spectra with the objective of developing high-intensity and efficient lighting sources for commercial and industrial applications. Much of the emission work done on the spectra of transition-metal diatomics (oxides, nitrides, fluorides, and chlorides) with this instrument by Bernath (University of Waterloo), Davis (UC-Berkeley), and O'Brien (Southern Illinois University, Edwardsville) has led to a wealth of new information about the electronic structure of these molecules, which not only benefits astronomy, but is also of equal importance to the area of high-temperature chemistry.

It should be noted that the combination of the high-resolution FTS coupled to a large solar telescope with infrared capability makes this facility ideally suited for research involving the chemistry of the atmosphere of the Earth.

## APPENDIX D

#### **NSO MANAGEMENT ROSTER**

Stephen Keil	Director
Mark Giampapa	Deputy Director
Thomas Rimmele	ATST Project Scientist and Solar Adaptive Optics Program PI
Jim Oschmann	ATST Project Manager
Jack Harvey	SOLIS Project Scientist
Jeremy Wagner	SOLIS Project Manager; ATST Deputy Project Manager
Stephen Hegwer	ATST Site Survey Manager
John Leibacher	GONG Program PI
Pat Eliason	GONG Program Manager
Rex Hunter	Site Manager, Sacramento Peak

## NOAO Managers Who Provide NSO Program Support

Karen Wilson	Associate Director for Administration and Facilities
James Tracy	Controller
Larry Daggert	Manager, Engineering and Technical Services (ETS)
Steve Grandi	Manager, Central Computer Services (CCS)
Sandra Abbey	Human Resources Manager
John Dunlop	Manager, Central Facilities Operations & Kitt Peak Facilities
Doug Isbell	Manager, Public Affairs and Educational Outreach
Patrick Phelan	Financial Manager

## APPENDIX E

## SCIENTIFIC STAFF PERSONNEL STATISTICS

Hired			
Date	Name	Position	Site
01/01/03	John A. Eddy	(Visiting) Scientist	NSO/T
05/19/03	Irene Gonzalez-Hernandez	Junior Scientist	NSO/T
05/19/03	Shukirjon S. Kholikov	Junior Scientist	NSO/T
Completed	Employment		
01/14/03	Thierry Corbard	Junior Scientist	NSO/T
Changed St	tatus		
04/01/03	Rachel Howe	Promotion to Assistant Scientist	NSO/T
04/01/03	Rudolph W. Komm	Promotion to Assistant Scientist	NSO/T
Visitors (one month or longer)			
01/16/03	Alessandro Cacciani	University La Sapienza. Italy	NSO/SP
09/01/03	Isroil Sattarov	Astronomical Institute of the Uzbek	
		Academy of Sciences, Uzbekistan	NSO/SP