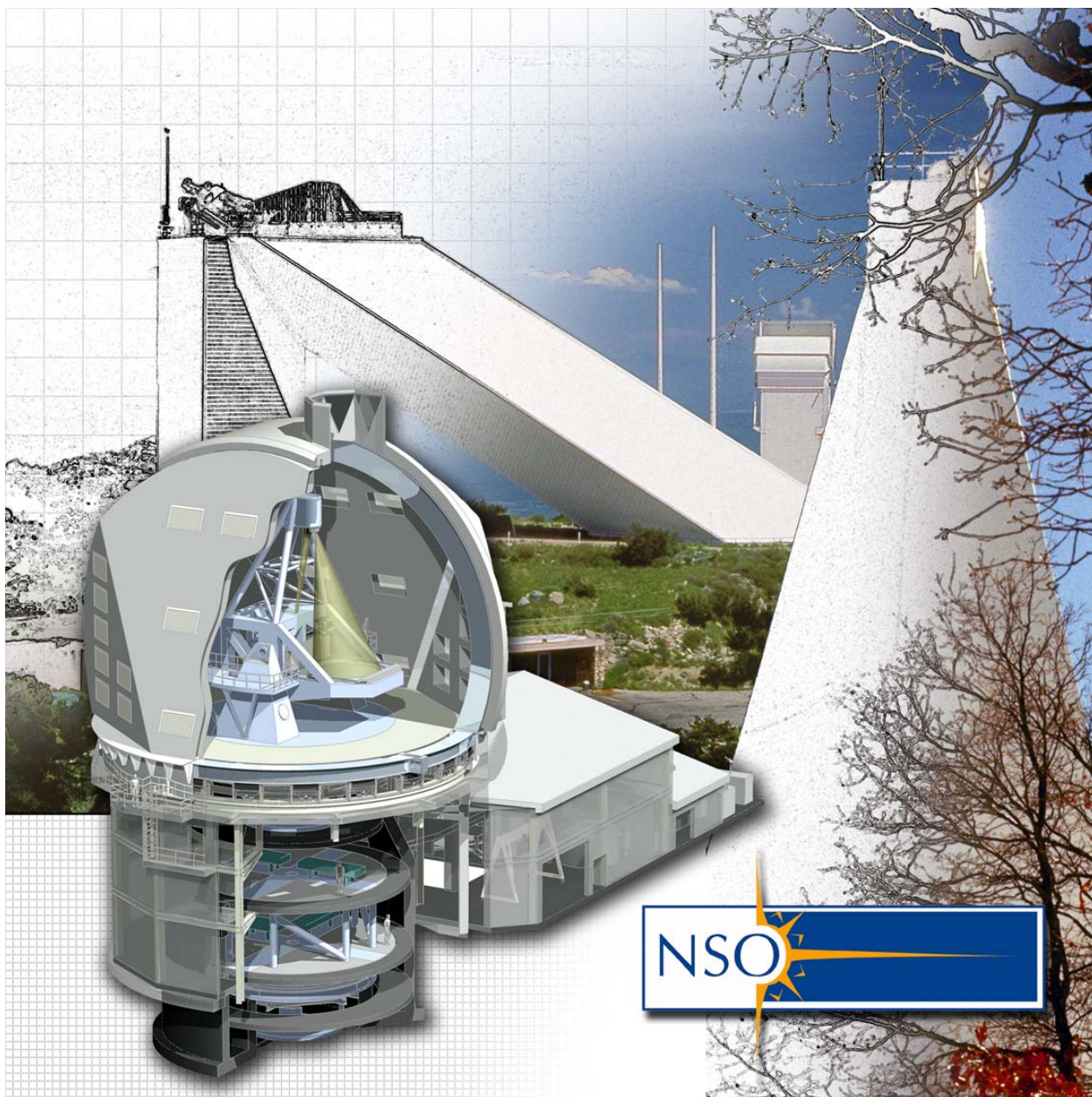


NATIONAL SOLAR OBSERVATORY



FY 2004 Annual Program Plan

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MISSION

The mission of the National Solar Observatory 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 mission includes the operation of cutting edge facilities, the continued development of advanced instrumentation both in-house and through partnerships, conducting solar research, and educational and public outreach.

NSO accomplishes this mission by:

- providing leadership for the development of new ground-based facilities that support the scientific objectives of the solar and solar-terrestrial physics community;
- advancing solar instrumentation in collaboration with university researchers, industry, and other government laboratories;
- providing background synoptic observations that permit solar investigations from the ground and space to be placed in the context of the variable Sun;
- providing research opportunities for both undergraduate and graduate students, helping develop classroom activities, working with teachers, and mentoring high school students;
- innovative staff research.

RESEARCH OBJECTIVES

The broad research goals of NSO are to:

- **Understand the mechanisms generating solar cycles** – Understand mechanisms driving the surface and interior dynamo and the creation and destruction of magnetic fields on both global and local scales.
- **Understand the coupling between the interior and surface** – Understand the coupling between surface and interior processes that lead to irradiance variations and the build-up of solar activity.
- **Understand the coupling of the surface and the envelope: transient events** – Understand the mechanisms of coronal heating, flares, and coronal mass ejections which lead to effects on space weather and the terrestrial atmosphere.
- **Explore the unknown** – Explore fundamental plasma and magnetic field processes on the sun in both their astrophysical and laboratory context.

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I INTRODUCTION

Major components of the National Solar Observatory (NSO) long-range planning include:

- Developing the 4-meter Advanced Technology Solar Telescope (ATST) on behalf of, and in collaboration with, the solar community;
- Expanding the NSO current solar adaptive optics (AO) program to achieve diffraction-limited imaging at solar telescopes at NSO and at other institutions, and to develop the AO and multi-conjugate AO (MCAO) technology needed for the ATST;
- Operating the current high-resolution and IR flagship facilities and maintaining their competitiveness through AO and state-of-the-art instrumentation until the ATST is online;
- Operating a suite of instruments comprising the Synoptic Optical Long-term Investigation of the Sun (SOLIS);
- Operating the Global Oscillation Network Group (GONG) telescopes;
- An orderly transition to a new NSO structure, which can efficiently operate these instruments and continue to advance the frontiers of solar physics.

NSO has been charged by the US community of solar researchers, through recommendations of the National Academy of Sciences/National Research Council (NAS/NRC) Astronomy and Astrophysics Survey Committee Decadal Survey, with a continuing mandate to provide forefront optical research facilities for the use of the community. In addition, NSO collaborates with and provides expertise to other institutions wishing to improve their facilities. NSO also acquires and distributes solar observational data to the research community and the public.

The FY 2004 program outlined in this plan will continue to further these long-range objectives. The plan presents in detail what NSO proposes to accomplish in FY 2004 with the \$12,072K budgeted by the NSF Astronomy Division for solar physics and with the additional funds received from NSO's partnering organizations. The plan discusses how the 2004 program supports the strategic goals of solar physics and where increased funding would enhance the NSO program to achieve the long-range goals more rapidly.

The sections that follow describe the NSO plan to renew its facilities, ongoing operations, and new instrumentation. Included are descriptions of major initiatives, current facilities, and support provided to principal investigators and other members of a broad community that rely on solar data to pursue space and terrestrial research and to conduct space weather forecasting operations. The active NSO programs to train solar astronomers, in education, and in public outreach are described. The NSO management structure and investment plan are also presented. The appendices provide information on new and completed milestones, detailed budgets, scientific research and service of the staff, and detailed organizational charts.

II NEW SCIENTIFIC CAPABILITIES

To fulfill its mission and achieve the research objects listed at the beginning of this plan, NSO has developed a program with a robust mixture of new initiatives, support for ongoing operations, and staff research. The NSO program is closely aligned with the recommendations of the NAS/NRC Astronomy and Astrophysics Survey Committee (AASC) decadal survey report, *Astronomy and Astrophysics in the New Millennium*, the NAS/NRC Solar and Space Physics Survey Committee decadal survey report, *The Sun to the Earth and Beyond*, and with the NAS/NRC report on “Ground-Based Solar Research: An Assessment and Strategy for the Future.” These reports place a high priority on the development of a new high-resolution facility for solar physics. They also emphasize the need for the collection of ground-based solar synoptic data and the need for data management on a national scale. NSO's major initiatives, and its instrumentation program, described in this program plan, support the recommendations of these studies.

Figure II-1 is a roadmap showing the planned evolution of NSO facilities and capabilities over the next several years. During FY 2003, the SOLIS vector spectromagnetograph (VSM) replaced the Kitt Peak Vacuum Telescope (KPVT), which was then closed after obtaining a few months of overlapping data. As the other SOLIS instruments become operational in FY 2004, NSO will replace many of its existing synoptic programs with SOLIS. The enhanced GONG achieved full operational status in FY 2003, and real-time access to GONG magnetographs for space weather research will be completed in FY 2004. Working closely with the solar community, NSO will continue the design and development phase for the ATST. The ATST construction proposal was submitted in early FY 2004. During FY 2004, the ATST design will be readied for a preliminary design review during the latter part of calendar year 2004. The goal is to be ready to start construction in FY 2006.

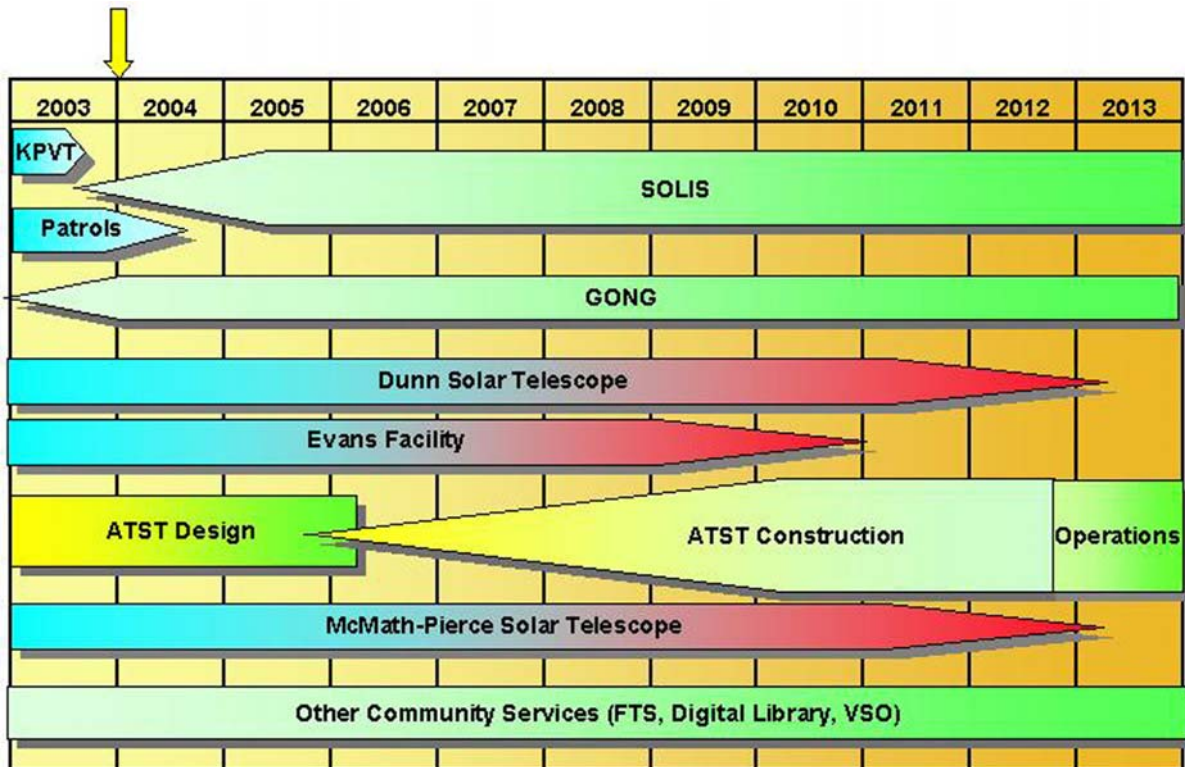


Figure II-1. Strategic Road Map of NSO Facilities

In addition to operating major facilities for the solar community, NSO conducts several community service functions. These include: operating the Fourier Transform Spectrometer (FTS) in support of atmospheric chemistry, planetary physics and other programs; development of an on-line digital library for synoptic solar observations; and planning for a Virtual Solar Observatory (VSO). While these programs change with time, they represent an important role that NSO plays, and plans to continue, for the community. As the new facilities come on-line, NSO will implement plans for the logical decommissioning or transitioning of the older facilities.

1 Initiatives

1.1 Advanced Technology Solar Telescope Project

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 (≤ 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>.

Highlights from this past year include completion of the ATST Science Requirements Document, completing the early major design trades, down selecting from six candidate sites to three, and successful completion of the Conceptual Design Review. The construction proposal was also completed and submitted prior to the end of calendar year 2003.

1.1.1 ATST Progress

The current ATST organization is shown in Appendix G. People with NSO or USAF designations are being contributed to ATST from NSO base funds or USAF funds. Others within the NSO are contributing to the design and organization. There are planned additions to the ATST NSO staff for adaptive optics, electronics, and other areas as needed.

The team completed the major trades identified in previous years that have resulted in confirmation of the off-axis design, an altitude-azimuth mount, and a hybrid-ventilated enclosure to control the local environment. Several initial instrument concepts were developed and interfaced to the telescope design at the coudé area. The systems error budget was developed and expanded to include bottom-up performance estimation through Monte Carlo techniques based upon actual site data for input to the model. The conceptual design review committee was formed and a well-attended design review was held at Sunspot in August 2003. The design concepts were well received and the project was given very good guidance and suggestions from the conceptual design review (CoDR) committee as well as the science working group (SWG), both of which reported on our progress. The CoDR committee and SWG reports and our actions resulting from this first major review are available through the ATST Web site (<http://atst.nso.edu>). The concept resulting from the conceptual design phase is shown in Figure II-2.

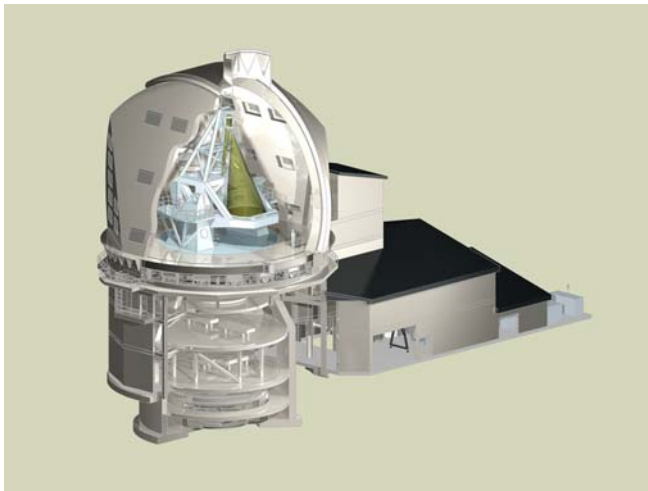


Figure II-2. ATST concept. The concept has a non-co-rotating ventilated dome, an Alt-Az mount configuration, a 4-meter off-axis Gregorian optical design, and a simple-heel optics arrangement to send the beam to a large two-level rotating coudé lab to allow maximum instrument flexibility. This design includes a convenient location for a high-order deformable mirror for efficient inclusion of adaptive optics from the beginning. It also represents a compromise of the most compact telescope mount arrangement with the largest lab space that supports efficient image de-rotation.

The basis for project planning for the construction proposal was established with the development of a detailed work breakdown structure (WBS) with associated costs and schedule. A WBS dictionary document summarizes each work package and identifies the budget, schedule, and responsible manager. The respective engineering areas created bottom-up estimates, made comparisons with similar work from other observatories such as SOAR and Gemini, and obtained industry estimates from various funded and unfunded design evaluation studies. The only unsuccessful major effort during the past year was our ability to obtain funding and permission to purchase the primary mirror blank as a long-lead item. Efforts will continue for this in the coming months.

The primary effort in instrumentation has been through our Co-PI and partner teams:

High Altitude Observatory (Visible Light Polarimeter Design).

University of Hawaii (Near IR Polarimeter Design).

New Jersey Institute of Technology (Tunable IR Filter Design).

Lockheed Martin (Broad-band Filter).

NASA Marshall SFC (Visible Tunable Filter/Polarimeter Design).

NASA Goddard SFC (Thermal IR Instrument Design).

Other partner activities supporting the Phase I site survey were completed. This included equipment developed at the University of Hawaii that was delivered to each site, and site testing support from a number of partners. The University of California, San Diego completed their stray light analysis work.

1.1.2 ATST Site Selection

The ATST Site Survey Working Group (ASWG) with broad community participation was very active this past year. This committee has representatives from current collaborators and other nations that have expressed interest in participating in the ATST. Substantive progress on the site survey has been made. As of December 2003, the following have been accomplished:

- Phase I of the ATST site survey at six sites was completed.
- We have down-selected to three sites for further testing and analysis:
 - Big Bear Solar Observatory, California;
 - Mees Solar Observatory, Haleakala, Hawaii;
 - Observatorio Roque de Los Muchachos, La Palma, Canary Islands, Spain.

- The first phase of the data reduction package and initial analysis of Phase I data were completed.
- The Phase II plan for continued site testing has begun.

1.1.3 Near-Term Plans

Following the work breakdown structure and schedule for the design and development phase, the project will continue its design efforts in preparation for the preliminary design review. This will include the involvement of industry in the preliminary design and working with the partnership through established work packages for instrumentation and site survey completion.

In support of design activities, error budgets were established for key observing scenarios including on-disk observations with adaptive optics, seeing limited on-disk observations, seeing limited coronal observations, and polarization. Further details and models needed to evaluate and meet these error budgets will be developed. Models required to support the remaining design and trade activities include: thermal control, especially with respect to the instrument lab environment, dynamic structural analysis, and Monte Carlo-based performance estimates incorporated into our error budget system. Other design and analysis needed to support the major reviews include implementation of CoDR recommendations in areas such as design of a Gregorian rotator, enclosure thermal control, instrument interfaces and facility requirements. Optical interfacing to potential instrument designs, such as visible and near-IR spectral polarimeters, that are consistent with the telescope and facility conceptual designs, will continue through working with our partners. We plan to schedule two remaining major reviews during the design and development phase, including:

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 draft integration, testing and commissioning plans.

Final System Design Review (2005)

- Preparing construction detailed design and specifications at the system level.
- Procurement planning.
- Integration, test and commissioning planning.
- Operational planning.

We will likely have one or two additional workshops involving our partners and community representatives as the system design evolves over the next two years.

Additional information about the ATST and the science goals it will fulfill are available at <http://www.nso.edu/ATST>.

1.2 Adaptive Optics (AO)

High-resolution observations of the Sun are essential in solving many of the outstanding problems of solar astronomy. The current high-resolution solar telescopes are in the one-meter class. Without AO the resolution of these telescopes is limited to about 1 arcsec (long exposure) because the Fried parameter (roughly speaking, the largest aperture telescope that would have diffraction-limited seeing) of a good daytime site is about 10 cm. AO is necessary to obtain full benefit from existing telescopes.

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 (MRI) 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 systems will upgrade each of these high-resolution solar telescopes and greatly improve their scientific output. The resulting systems 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 that has been operating at the DST since 1998, the high-order AO system provides a threefold increase in the number of deformable mirror actuators that are actively controlled.

During FY 2003, the AO project has made excellent progress and is well on track towards a timely completion of the project. In April 2003, the high-order AO system was operated 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. Several “shared-risk” science runs were performed with the high-order AO at the DST by local staff and in collaboration with, for example, members from NJIT and the University of Hawaii Institute for Astronomy (IFA). All of these runs have produced excellent results (see December 2003 *NOAO/NSO Newsletter* 76).

The Diffraction-Limited-Spectro-Polarimeter (DLSP) is the main instrument fed by the high-order AO. The first diffraction-limited vector magnetic field observations with the DLSP-high-order AO instrument combination were performed during FY 2003. Current efforts are focused on completing the integration of the DLSP and improving the user-friendliness of the AO system. The instrument combination will become available for general use in July 2004.

The BBSO AO system was deployed in December 2004. The NSO AO team integrated the AO system into the BBSO optical setup and closed the servo loop at BBSO. Engineering runs at BBSO are in progress in order to evaluate the performance of the BBSO system.

During FY 2004 the low-order AO system at the DST will be upgraded to a high-order AO system. This will provide two identical AO systems, well matched to the seeing conditions at the DST and feeding two different instrument ports that can accommodate a variety of facility-class instrumentation, such as the DLSP and the new Spectropolarimeter for Infrared and Optical Regions (SPINOR), as well as experimental setups and visitor instruments such as the Italian BI-dimensional Spectrometer (IBIS). This will make the DST the most powerful facility in terms of post-focus instrumentation.

Another important aspect of this project is the development of AO data-reduction techniques and tools. The interpretation of AO data for an extended object like the Sun is challenging. The AO point spread function, and temporal and spatial variations thereof, must be understood in order to be able to interpret high-resolution imaging and spectroscopic data of solar fine structure. The performance limitations of solar AO systems also have to be understood. AO technology and AO data-reduction tools are being developed by a graduate student

and in collaboration with the Center for Adaptive Optics and researchers at the Herzberg Institute in Canada. A second graduate student working for the AO project at NSO graduated from NJIT in FY 2003.

With the nearing completion and deployment of the high-order AO systems at the DST and at BBSO, the technical efforts of the AO project are now focused on the development of multi-conjugate adaptive optics (MCAO). The Sun is an ideal object for the development of MCAO since solar structure provides the “multiple guide stars” needed to determine the wavefront information in different parts of the field of view. During FY 2003 MCAO wavefront sensor data were collected at the DST and analyzed. Based on these measurements, an MCAO proof-of-concept experiment has been devised. This experiment will be performed at the DST using the two existing deformable mirrors placed at conjugates of two different altitudes in the atmosphere. The optical design for the experiment has been completed. The main goals for FY 2004 are the completion of software development for MCAO real-time wavefront sensors and development of MCAO control algorithms. The first engineering run with the MCAO system is planned for the end of FY 2004. The project will strive to work closely with other MCAO efforts at such institutions as the National Optical Astronomy Observatory (NOAO), the Center for Adaptive Optics (CfAO), and the Gemini Observatory.

1.3 SOLIS

The SOLIS suite of instruments has embarked on a program of producing high-quality synoptic solar data over a period that covers a few solar cycles. SOLIS (Synoptic Optical Long-term Investigations of the Sun) is a project to make optical measurements of processes on the Sun, the study of which requires well-calibrated, sustained observations over a long time period. The project was started in mid FY 1998 and completing it has taken about two years longer than originally planned. A major reason for the delay was the inability of a vendor to provide custom CCD cameras, and the need to find an interim camera supplier. The major SOLIS instrument, the vector spectromagnetograph (VSM), started observations in the summer of 2003 using the interim, less capable cameras. A period of making simultaneous observations with the VSM and the old Kitt Peak Vacuum Telescope (KPVT) was carried out with good results. The 30-year record of data from the KPVT can be adequately tied to the new data from the VSM. Accordingly, the KPVT was closed on September 22, 2003, after 30 years of outstandingly productive service. Its daily observation program is being continued using the SOLIS VSM at a temporary, nearby site that is exceedingly convenient for debugging purposes.

Initial data from the VSM confirm the innovative concept of the instrument and set a new standard for full-disk measurements of the solar magnetic field at moderate spatial resolution. The line-of-sight component of the magnetic field is measured with 20 times the sensitivity of the old KPVT equipment so that the entire disk of the Sun shows fields above the noise level. Starting on August 30, 2003, full-disk vector magnetograms are being made for the first time. These reveal a wealth of fascinating and unexpected properties of the solar magnetic field.

At present, the VSM is hampered by minimal data recording capability at the temporary observing site. Consequently, the observing program is limited. Significant effort is being expended to develop and streamline a data reduction pipeline for standard data products. However, the high quality of the data has revealed that some algorithms used previously are no longer adequate. For example, measurements of the chromospheric magnetic field cannot be done as previously because the spectrum line sometimes shows emission components in localized regions that foil simple data reduction methods. A new, more robust algorithm is under development.

The other major instruments, the integrated sunlight spectrometer (ISS) and full-disk patrol (FDP) are installed in a laboratory with a sunlight feed. Both instruments have produced good quality data. Work on the ISS and FDP is slowed by a shortage of personnel and demands of higher priority projects.

The budget available for operating SOLIS is only about 60% of what was originally proposed. Furthermore, long-time partner support of the synoptic program by NASA and NOAA has diminished or ceased. Accordingly, three proposals for non-NSF funding to help operate and do science with SOLIS were prepared and submitted. Without this additional funding, SOLIS will have to be operated on a shortened, non-daily observing schedule.

Early in 2004, SOLIS will be moved to Kitt Peak, where it will be mounted on top of the former vacuum telescope building. Once all of the SOLIS instruments are completed and consistently produce high-quality data, NSO will propose to build two additional SOLIS units in response to the desired capability outlined in the NAS/NRC decadal survey, "Astronomy and Astrophysics in the New Millennium." These will be placed at distant longitudes and operated in collaboration with foreign partners to form a SOLIS network capable of much more complete coverage of transient solar activity.

2 Instrumentation Program

2.1 Diffraction-Limited Spectro-Polarimeter (DLSP)

The diffraction-limited spectro-polarimeter is a collaboration between the High Altitude Observatory and NSO. The DLSP will permit different image scales, from high-resolution (at the diffraction limit of the Dunn Solar Telescope) to lower resolution with a larger field-of-view. This project consists of two phases: Phase 1 integrated the DLSP with the low-order AO system and existing CCD hardware on Port 4. Using the existing Advanced Stokes Polarimeter (ASP) modulation and demodulation unit, Phase 1 was 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.

The DLSP instrument is completed and now being tested at the DST using the low-order adaptive optics and the ASP control system. The instrument saw first light on March 13, 2002. The initial results show that the performance of the instrument in the high-resolution mode is better or comparable to that of the ASP. Note that the spatial resolution achieved using the ASP is around 0.8 arcsec.

The DLSP Phase 2 was successfully operated during an engineering run in October 2003 and integrated with high-order adaptive optics. The instrument is being fine-tuned and a user-friendly graphical user interface (GUI) is under development. The DLSP is expected to become a user instrument during Spring 2004.

2.2 Narrow-band Filter Upgrade

This project will begin in FY 2004 with the goal of providing high throughput narrow-band imaging. It will replace the UBF+Fabry-Perot filter currently in use. Most of the hardware has been purchased and the project awaits technical and programming support to bring it online.

2.3 Large-Format Infrared Array and Controller

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

NSO's plan for 1-5 μm observations takes full advantage of NOAO's investment in the ALADDIN infrared array development project. With 16 times as many pixels, higher quantum efficiency, lower read-out noise, and better immunity from electronic interference, the $1\text{K} \times 1\text{K}$ ALADDIN-based camera will be superior to the current 256×256 (NIM) camera in every respect and will enable new types of scientific observations, such as vector magnetograms of weak-field concentrations and high-cadence studies of chromospheric dynamics.

A high-quality ALADDIN-III array has been identified and assigned to NSO by NOAO at no cost to NSO. A contract for the camera controller was signed with Mauna Kea Infrared (MKIR), and is nearing completion. An initial simple dewar, designed to be upgraded with cold re-imaging optics in the future, has been ordered through MKIR. The design has been completed and dewar fabrication has begun. MKIR will then integrate the controller with this dewar. Delivery is expected in early 2004, with initial science observations later that year.

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.

2.4 Spectro-Polarimeter for Infrared and Optical Regions (SPINOR)

SPINOR is a joint HAO/NSO program to upgrade the existing advanced stokes polarimeter (ASP) at the Dunn Solar Telescope. The ASP has been the premier solar research spectro-polarimeter for the last decade. Its ability to explore new spectral lines and to observe in multiple lines simultaneously is still unique. However the ASP wavelength range is restricted to the visible, limiting its ability to sample new solar diagnostics, and its hardware is becoming outdated and difficult to maintain. HAO has received National Center for Atmospheric Research (NCAR) funding to start building SPINOR. SPINOR extends the wavelength of the ASP from 750 nm to 1600 nm with new cameras and polarization optics, provides improved signal-to-noise and field of view, and replaces obsolete computer equipment. Software control of SPINOR will be brought into the DST control system as opposed to the stand-alone ASP. SPINOR will augment capabilities for research spectropolarimetry at the DST and extend the lifetime of state-of-the-art research spectropolarimetry at the DST for another decade.

2.5 McMath-Pierce Telescope Control System (TCS)

Upgrades to the McMath-Pierce telescope control system are needed to ensure that the facility remains competitive and maintainable. Until the end of FY 2004, only minor planning and test efforts are envisioned due to limited resources. Test efforts have included the investigation of a new guider approach that will be completed and, if successful, commissioned during FY 2004. The TCS upgrade will take advantage of existing engineering experience within NSO, experience gained in the SOLIS project, as well as experience being gained with the commercial TCS of the upgraded East Auxiliary telescope.

2.6 Image Improvements at the McMath-Pierce

2.6.1 Seeing Improvement

Understanding the internal seeing in a solar telescope is a crucial prerequisite for the detailed design of the ATST. Further tests and modifications of the McMath-Pierce telescope to reduce its internally generated seeing will be driven by the need of more information for designing the ATST. The performance of such improvements will be assessed with a high-order wavefront sensor that has been developed for the McMath-Pierce adaptive optics project (see below).

2.6.2 Adaptive Optics

The low-cost infrared adaptive optics system at the McMath-Pierce telescope was commissioned in FY 2003 and is being used for many scientific investigations. A few minor modifications will be carried out in FY 2004 to enlarge its field of view and to improve its performance.

III SUPPORT TO PRINCIPAL INVESTIGATORS AND THE SOLAR-TERRESTRIAL PHYSICS COMMUNITY

1 NSO Telescope Operations

Ongoing upgrades to their focal plane instrumentation have allowed NSO telescopes to remain extremely productive and among the most useful solar telescopes in the world. Although the major NSO telescopes are three or more decades old, they still play a key role in support of US and international solar research. The NSO telescope upgrade and instrument development program is guided by the scientific and technical imperatives for a new ATST. Consequently, 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.

1.1 Flagship Facilities

1.1.1 Dunn Solar Telescope (DST)

The 76-cm Dunn Solar Telescope, located on Sacramento Peak at an altitude of 2804 m, is the premier facility for high-resolution solar physics. It is an evacuated tower telescope with a 1.6-m secondary stopped down to 76 cm by the entrance window. The evacuated light path eliminates internal telescope seeing. A high-order adaptive optics system that provides diffraction-limited seeing under moderate to poor conditions was recently completed. This system will be commissioned in FY 2004 and become available to users. Over the past several years, NSO has pioneered solar adaptive optics and high-resolution, ground-based solar physics as a necessary prelude to the ATST.

Past DST observations have played a key role in understanding the solar photosphere and chromosphere and have provided fundamental knowledge about convective processes at the solar surface, small-scale magnetic fields, and the excitations of solar p-mode oscillations. More recently, high-resolution spectral and polarimetric observations with the DST have provided evidence of magnetic reconnections, the nature of flows in sunspot penumbra, twisting motions prior to solar activity, and oscillatory magnetoconvection. Recent observations of a solar active region that combined high-order adaptive optics and the diffraction-limited stokes polarimeter have revealed fine super structure in flares and sunspot magnetic fields at the diffraction limit of the DST. This combination of AO and DLSP will open up new horizons in attempts to understand magnetoconvection and its consequences in the solar atmosphere and will provide strong scientific impetus for the ATST.

NSO will vigorously pursue the opportunity presented by high-resolution, diffraction-limited imaging at the DST with a goal of refining ATST science objectives and requirements, and ensuring growth of the expertise needed to fully exploit ATST capabilities. With the advent of AO, the DST has seen a large increase in proposal pressure and the over-subscription rate, which is nearing 100%. Major science topics that the DST is ideally suited to pursue include:

- *Transient eruptions.* Flux tube evolution and interactions that trigger activity.
- *Origins of solar variability and atmospheric heating.* Role of small-scale flux tubes, convection, and waves.
- *Surface and atmospheric structure.* Fields and flows in magnetic structures such as sunspots, pores, filaments, and prominences.

To support this science, the DST houses the wealth of instruments (see Table III-1).

1.1.2 McMath-Pierce Solar Telescope (McMP)

The McMath-Pierce Solar Telescope (McMP) on Kitt Peak, at an altitude of 2096 m, is currently the largest unobstructed-aperture optical telescope in the world, with a diameter of 1.5 m. Thus, it is uniquely capable of panchromatic, flux-limiting studies of the Sun. In particular, it is the only solar telescope in the world on which investigations in the relatively unexplored infrared domain beyond 2.5 microns are routinely accomplished. The large light-gathering power, the extended wavelength range from the UV to the far IR, and the well-behaved polarization characteristics of the telescope are unique and have led to the first direct measurements of kilogauss magnetic fields outside of sunspots and the discovery of cold structures in the solar chromosphere. The East and West Auxiliary telescopes are among the largest solar telescopes (both with 0.9-m diameter and 0.8-m clear aperture) and share the same all-reflective, unobstructed design of the main telescope. Adaptation of the low-order AO system for diffraction-limited imaging in the IR has been initiated. A large-format 1024×1024 ALADDIN array camera system is also being developed as described on page 14.

Infrared polarimetry and infrared imaging developed at NSO have been combined with the McMath-Pierce Telescope to produce unparalleled, detailed magnetic maps of the photosphere. These maps reveal a ubiquitous presence of weak fields associated with turbulent convection at the solar surface that could play an important role in solar magnetic flux loss and heating of the outer solar atmosphere. Other observations with these systems have measured chromospheric magnetic fields and may provide the opportunity to directly observe coronal magnetic fields.

NSO will continue its pursuit of forefront themes in infrared solar physics, including:

- *The “dark matter” of solar magnetism.* Subkilogauss magnetic fields in the photosphere.
- *The origin of chromospheres.* The complex and unexpected structure of the transition between photosphere and chromosphere as revealed by the precise thermometer of the carbon monoxide molecule.
- *The magnetic field in the solar corona.* Measured with the near-infrared line pair Fe XIII 1074.7/1079.8 nm and potentially with the newly discovered Si IX line at 3932 nm.
- *Discovery.* Much of the infrared spectrum is still barely explored, especially in flares, sunspots, and the corona.

The Fourier Transform Spectrometer (FTS), located at the McMath-Pierce Solar Telescope Facility, is a unique national resource in wide demand by atmospheric physicists and chemists, as well as astronomers. The FTS is a highly stable, Michelson interferometer enclosed in a vacuum chamber. It is the only instrument of its kind in routine operation with capabilities for spectroscopy not available anywhere else in the world. With a total spectral coverage from 0.2 microns to 20 microns, the FTS simultaneously achieves high spectral resolution, excellent signal-to-noise ratio and wide bandpass.

The FTS is thus able to produce high-quality measurements of spectral line positions, strengths and widths. The McMath-Pierce FTS is a multi-disciplinary facility that is utilized for research programs in solar physics, laboratory spectroscopy and atmospheric sciences. Results from FTS laboratory studies have been crucial to the interpretation of data derived from the Arctic and Antarctic ozone campaigns. The unique combination of a large solar telescope with infrared capability and a high-resolution FTS instrument is ideally suited for conducting atmospheric research at this facility. More than two-dozen

molecules in the Earth's atmosphere, which have been identified in the McMath-Pierce FTS solar spectra, are being monitored during each observational run. The McMath-Pierce facility has been designated as an official complementary site for the Network for the Detection of Stratospheric Change (NDSC). The Earth atmospheric measurements that are made at this facility are included in the NDSC archive.

1.1.3 Global Oscillation Network Group (GONG)

The Global Oscillation Network Group (GONG) is an international, community-based program to conduct a detailed study of the internal structure and dynamics of the Sun using helioseismology. In order to exploit this technique, GONG developed a six-station network of automated and extremely sensitive and stable solar velocity imagers located around the Earth to obtain nearly continuous observations of the Sun's "five-minute" oscillations. GONG's network provides essentially continuous observations of the solar velocities, ensuring that at least two sites can see the Sun at all times. This overlap minimizes data lost to bad weather or technical problems, and at the 90% coverage level the few remaining gaps can reliably be "filled in" to produce an essentially continuous data set. GONG's 1024^2 pixel cameras obtain velocity, intensity, and magnetic-field images of the Sun's surface every minute. Once a week the data is shipped to project headquarters, where the data from all six sites are calibrated and merged to obtain frequencies and other products, which are made available to the community.

In addition to the operation of the instrument network, GONG has developed a data reduction and analysis system to process the observations, and facilitate the activities of the scientific community. GONG now collects 32 times more data than it did in its initial configuration, and a high-performance data handling system and data processing pipeline system is now operational, and the scientific analysis modules are undergoing testing.

Results to date have substantially advanced our knowledge of the Sun's structure and dynamics, testing fundamental theories of physics and astrophysics, and we are now beginning to measure significant structural variation with the solar sunspot cycle, as well as on shorter time scales. With GONG's increased spatial resolution, we are also able to carry out local helioseismology, which uses running acoustic waves to study small-scale three-dimensional features below the Sun's surface.

NSO will operate the GONG's network of instruments to refine its measurements of the time-averaged solar structure and to pursue the systematic variations in the structure of the solar interior with magnetic activity. GONG will continue to pursue opportunities, advancing the major topics in helioseismology and solar physics, including:

- *Global p-modes to high spherical harmonic degree ($\ell \approx 1000$).* Global helioseismology to high spherical harmonic degree to probe closer to the solar surface.
- *Local helioseismology.* Local helioseismology to probe the inhomogeneous and intermittent structure below the surface (tracking and remapping for time distance, ring diagrams, acoustical holography analysis).
- *High-resolution, high-cadence magnetograms.* Continuous, high signal-to-noise ratio, high spatial-resolution magnetograms will be of broad interest and extend the SOLIS data by providing a continuous temporal context.

- *Farside imaging.* Near-real-time images of the farside of the Sun will help forecast active regions up to two weeks before they rotate into view, providing useful information to a broad range of users ranging from solar astronomers planning upcoming observing campaigns to space weather forecasting.

1.2 Synoptic Facilities

1.2.1 Evans Solar Facility (ESF)

The Evans Solar Facility provides a 40-cm coronagraph as well as a 30-cm coelostat. The Evans coronagraph is the largest in the US and most thoroughly instrumented in the world. The coronagraph feeds a universal spectrograph, spectroheliograph, Littrow spectrograph, chopping coronal photometer, and a bench where PI instruments can be set-up. The most recent instrumentation was a visible and IR coronal polarimeter, which produced tantalizing observations of coronal magnetic fields. This new instrumentation will provide core capabilities for the next generation of ground- and space-based coronal telescopes. Although there is some strong community interest in exploiting the coronagraph, the decline in staffing levels resulting from years of level funding have left NSO unable to support its operation. Currently the US Air Force provides most of the operating support for the ESF to continue their synoptic coronal emission line program. Other users will be given access to the facility if they can provide their own support. Currently, HAO is planning to use the facility for some experiments.

In the past, the ESF 40-cm coronagraph supported a wide variety of research projects (e.g., coronal heating, coronal electric fields, chromospheric and coronal magnetic fields, heliospheric structure prediction, and cyclic variation of coronal structure). The ESF has provided limits of electric fields in the solar atmosphere, and discovered the rush to the poles in coronal emission lines as well as the extended solar cycle in coronal emissions. The ESF provides full-disk spectroheliograms in several bandpasses near the Ca II K-line and H α . There are no plans to upgrade these capabilities as these observations will be replaced by SOLIS.

1.2.2 Hilltop Solar Facility

The Hilltop facility houses the white-light and H α flare patrols, the coronal one-shot coronagraph, and a multi-band solar photometer. In addition, it has a coelostat that feeds an optical bench currently used for testing narrow-band filter systems and other instruments. The SOLIS Full Disk Patrol (FPD) is intended to replace the white-light and H α patrols, so upgrades of these systems have been frozen.

1.2.3 Kitt Peak Vacuum Telescope (KPVT)

The SOLIS VSM has replaced the daily magnetograms produced by the KPVT and the KPVT was decommissioned in September 2003. SOLIS will be housed inside the clam shell atop the KPVT tower.

Table III-1. Telescope and Instrument Combinations FY 2004

Key: DST = Dunn Solar Telescope ESF = Evans Solar Facility GONG = Global Oscillation Network Group
HT = Hilltop Telescope KPVT = Kitt Peak Vacuum Telescope

INSTRUMENT	TELESCOPE	COMMENTS/DESCRIPTION
NSO/Sacramento Peak – OPTICAL IMAGING & SPECTROSCOPY		
Low-Order Adaptive Optics	DST	20-mode correction
Advanced Stokes Polarimeter (ASP)	DST	Photospheric/chromospheric vector polarimetry, visible, 0.375 arcsec/pix
Universal Birefringent Filter (UBF)	DST	Tunable narrow-band filter, $R \leq 40,000$, 4200 - 7000 Å
UBF-Fabry Perot	DST	Tunable narrow-band filter, $R \leq 250,000$, 4200 Å - 7000 Å
Horizontal Spectrograph	DST	$R \leq 500,000$, 300 nm - 2.5 µm
Echelle Spectrograph	DST	$R \leq 2,000,000$, 300 nm - 2.5 µm
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies
Littrow Spectrograph	ESF	$R \leq 1,000,000$, 300 nm - 2.5 µm
Various CCD Cameras	DST/ESF/HT	380 - 1083 nm, Formats: 256×256 to $2K \times 2K$
Correlation Tracker	DST	Tip/tilt correction
40-cm Coronagraph	ESF	300 nm - 2.5 µm
Full-Limb Coronagraph	HT	Emission-line coronagraph
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å
Flare Patrol	HT	H-α and white-light full-disk images, 1 min. cadence
NSO/Sacramento Peak – IR IMAGING & SPECTROSCOPY		
Horizontal Spectrograph	DST	High-resolution 1 - 2.5 µm spectroscopy/polarimetry, $R \leq 300,000$
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 µm spectroscopy/polarimetry
NSO/Kitt Peak – IR IMAGING & SPECTROSCOPY		
Vertical Spectrograph	McMath-Pierce	0.32 - 12 µm, $R \leq 10^6$
1-m FTS	McMath-Pierce	2200 Å to 18 µm, $R \leq 600,000$
Near-IR Magnetograph	McMath-Pierce	Vector magnetograph, 1 - 2.5 µm, $R \approx 180,000$
IR Imager	McMath-Pierce	1 - 5 µm, 256×256 , 12 Hz, imaging spectroscopy, polarimetry
CCD Cameras	McMath-Pierce	380 - 1083 nm, up to 800×800 pixel
ZIMPOL I	McMath-Pierce	450 - 1100 polarimetry, 10 Hz, 300×400
IR Adaptive Optics (Prototype)	McMath-Pierce	2 - 5 µm, shared risk use with vertical spectrograph
Stellar Spectrograph	McMath-Pierce	380 - 1083 nm, $R \leq 10^5$
NSO/GONG – GLOBAL, SIX-SITE, HELIOSEISMOLOGY NETWORK		
Helioseismometer & Magnetograph	California, Hawaii, Australia, India, Spain, Chile	2.8-cm aperture; imaging Fourier tachometer of 676.8 nm Ni I line; 2.5 arcsec pixels; 1-min. cadence.

2 Digital Library and Virtual Solar Observatory (VSO)

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.

The advent of the Internet is the key enabler of alternate modes of observing and data delivery. The Internet enables direct interaction between astronomers at remote locations with the on-site observers and it allows rapid data dissemination. It will also allow observers to schedule observations with SOLIS automatically.

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 was released for public use as a beta version in December 2003 at <http://vso.stanford.edu/>. 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/>.

IV SCIENTIFIC STAFF

The primary roles of the NSO scientific staff are to carry out a balanced and forefront program scientific research, innovative instrument development, and observing support for the solar community. In addition to these primary roles, the NSO staff also participate in educational and public outreach activities through contributions at all levels, extending from preschool and K-12 through graduate and postdoctoral education. Through successful achievement in these multiple roles, the scientific staff is able to assume both a leadership role and a critical support role, in response to the needs and priorities of the community. In order to effectively carry out these roles, the responsibilities of a scientific staff member are divided between observatory service and scientific research. AURA policy establishes a goal of allocating 50% of an individual's time for the conduct of scientific research. Experience clearly confirms the AURA management view that maintaining a strong NSO scientific staff, with active research interests, is required in order to provide US solar physicists with the best solar facilities in the world.

The specific research interests and plans of individual NSF-supported scientific staff are described in detail in Appendix D. We present here an overview of the future research plans of the scientific staff according to broad themes in solar physics and related astrophysics.

1 Interior Structure and Dynamics

Helioseismology provides a unique tool to explore the otherwise invisible solar interior, and to test theories of the structure and dynamics of the solar interior as well as the dynamics of the near-surface layers which give rise to all of the manifestations of solar activity and space weather. NSO occupies a leadership role with the Global Oscillation Network Group (GONG) program, providing unique data to the community, as well as to a vigorous in-house research group.

Rachel Howe continues to study the global solar oscillations and the evolution of the solar interior rotation through the solar cycle, as well as other time-varying phenomena associated with the underlying physics of the cyclic changes, e.g., meridional flows. Rachel, Irene Hernandez-Gonzalez, Frank Hill, Shukur Kholikov, and Rudi Komm are pursuing the many phenomena that are uniquely accessible to the techniques of local helioseismology, including ring diagram, time-distance, and holographic imaging, with particular emphasis on time-varying flows from the surface down to the base of the convection zone. A variety of other studies are underway, including the near-real time imaging of the otherwise invisible farside of the Sun in support of a predictive space weather capability. Cliff Toner continues to develop the fundamental tools necessary to really understand the local helioseismic data, and John Leibacher is working on time series analysis techniques as well as the observational signature of the convective excitation of p-mode oscillations.

2 Solar Activity and Atmospheric Heating

The onset of the temperature rise that defines the chromosphere and, ultimately, the hot corona indicates that a non-thermal process heats the outer solar atmosphere. The advent of high-resolution, high-precision observations in the spatial, spectral and temporal domains can yield new insights on the intricate relationship between atmospheric dynamics and local magnetic fields that give rise to the non-radiative heating of the upper solar atmosphere.

NSO scientific staff pursue novel investigations of the solar chromosphere and corona in order to provide the observational framework for theoretical models of solar activity. For example, K. S. Balasubramaniam (Bala) will continue his efforts to understand the magnetic activity of the solar chromosphere using spectroscopic and polarimetric techniques. Bala, along with Han Uitenbroek, Jack Harvey and Harry Jones, is using observations obtained with the KPVT to conduct a careful study of the Zeeman splitting of the Ca II 854.2 nm line in order to more completely understand the magnetic influences on the formation of this chromospheric line diagnostic. Moreover, Han Uitenbroek and Bala are analyzing spatially and temporally resolved observations of the 854.2 nm line using the full Stokes capability of Uitenbroek's multi-dimensional radiative transfer code to significantly improve estimates of chromospheric magnetic field strengths. In addition, Bala and NSO Director Steve Keil will continue to analyze data acquired with the advanced Stokes polarimeter during the previous solar maximum in order to delineate the velocity and magnetic field characteristics of active region evolution for solar activity modeling. Finally, the link between the photosphere and the two-million-degree corona will be investigated by Alexei Pevtsov who will continue his work on the properties of X-ray bright points and the associated photospheric bipoles. Pevtsov will also examine the role of magnetic fields in coronal heating and the relationship between solar drivers and geomagnetic storms.

3 Solar Variability

A key discovery in astrophysics is that the Sun exhibits subtle but detectable variations in its radiative output. The irradiance variability of the Sun is indisputably related to magnetic structures that permeate the solar atmosphere. We now know that a variable solar "constant" must be taken into consideration when constructing models of global climate change. Although the causal links between the Sun's luminosity and spectral variability and the Earth's climate are not well understood, we cannot ignore the observed correlation between measurable climatic changes and solar variations.

One aspect of understanding the nature of solar variability is the relationship between spectral variability and the variations in the total irradiance of the Sun. Steve Keil is conducting a program to understand variations of the solar ultraviolet and extreme ultraviolet flux as inputs to the terrestrial atmosphere. As part of this broader program, Keil will specifically investigate changes in chromospheric emissions through measurements of the Ca II K-line in both integrated flux and spatially resolved spectroheliograms. The K-line variability can then be used as a ground-based proxy for solar UV and EUV variations. In a different approach to the study of the potential long-term behavior of the Sun, Mark Giampapa is investigating the range of variation of the chromospheric Ca II K-line in a homogeneous sample of solar-type stars. In principle, the study of a number of solar counterparts at random phases in their activity cycles should be indicative of the potential modes and amplitudes of the solar cycle.

When SOLIS becomes operational, several new and improved tools to study solar variability will become available. Since 1975, only the line profile of Ca II 393 nm has been recorded with fair frequency and good accuracy. Other spectrum lines have been recorded fairly accurately but with poor cadence. SOLIS's dedicated spectrograph will observe many spectrum lines several times per day with high photometric accuracy. An auxiliary imaging extinction monitor and an iodine vapor cell will allow frequent monitoring of atmospheric and instrumental effects that have previously been ignored. All of these improvements should enable a much better understanding of the physics of spectral irradiance variations and how they relate to total solar irradiance variations and Earth's climate and

atmospheric responses to these variations. The other instruments of SOLIS will directly address solar variability. They will provide new and improved observations of the Sun's magnetic field, and the photospheric, chromospheric and indirect coronal manifestations of magnetically-driven solar variability.

Carl Henney has been hired as the SOLIS Instrument Scientist. Henney will have primary overview responsibility for the operation of the SOLIS instruments. In addition, current NSO staff (both NSF staff and affiliated scientists) who have been actively involved in the utilization of the KPVT, such as J. Harvey and H. Jones, will continue their forefront work but with the new capabilities provided by the SOLIS VSM and full-disk patrol (FDP). The integrated sunlight spectrometer (ISS) is expected to be utilized by NSO staff who are conducting long-term, synoptic investigations of spectral line variability in the Sun as a star. Among these staff are S. Keil, W. Livingston (emeritus) and M. Giampapa. The FDP will provide data similar to that of the Hilltop Patrol facility and thereby enable the enhanced continuation of the research by staff and the community who have been associated with the Hilltop telescope.

4 Magnetic Fields and Atmospheric Structure and Dynamics

Han Uitenbroek has been investigating the three-dimensional structure and dynamics of the solar atmosphere using observations of vibration-rotation lines of the carbon monoxide molecule in the infrared near 4.7 microns. The observations, obtained with the NSO/McMath-Pierce telescope on Kitt Peak, reveal the important role solar granulation plays in the formation of these CO lines. In the coming year, Uitenbroek plans to continue research on CO line formation using infrared spectroscopy and radiative transfer modeling. He has extended this work to include the formation of lines of the CH molecule which are the main source of opacity in the widely used spectroscopic G-band. Together with Bala Uitenbroek will attempt to determine the field strength in small-scale magnetic elements from the polarization signal in CH lines in the G-band. In addition, Uitenbroek will use his numerical Stokes code to investigate the viability of H α polarimetry to measure chromospheric magnetic fields in addition to the use of the Ca II 854.2 nm line and the chromospheric Na I D lines. Using high-resolution imaging at the DST as well as Stokes spectropolarimetry from the ASP, Bala is working on understanding the dynamic structure of sunspots in the photosphere and the chromosphere.

Thomas Rimmele leads the NSO solar adaptive optics program. Rimmele will continue his efforts to perform observations at the highest spatial resolution, using both AO and frame selection techniques in order to study the properties and the dynamics of small-scale magnetic elements. In a related effort, Christoph Keller has successfully developed active and adaptive optics for the McMath-Pierce main telescope. Keller is using this system to observe small-scale magnetic fields and their relation with CO line strength variation in the chromosphere.

Matt Penn has completed the development of the NSO-California State University (CSUN) IR polarimeter system, and initial scientific work with the system produced three papers in 2003. New observations of the Evershed flow using molecular absorption lines, maps of a sunspot magnetic field in the Ti 2231nm line, and the temperature dependence of OH line absorption in sunspot umbra has been studied. Currently the system is being used to map the magnetic vector fields in sunspots using the Fe I 1565 nm g=3 line, the line with the largest Zeeman splitting in the visible or near-IR spectral region.

5 Laboratory Spectroscopy

Mike Dulick, who serves as the NSO McMath-Pierce/FTS Instrument Scientist for visiting investigators funded under an NSF Chemistry grant and a NASA upper atmosphere research grant for Laboratory Fourier Transform Spectroscopy, will continue using the FTS to record laboratory spectra of diatomics in the infrared and visible to aid in the interpretation of sunspot spectra. Dulick will also continue to lead projects to upgrade the detectors and data collection system for the FTS.

6 NSO Outreach to the Community: A Brief Overview

Through the enterprise of its scientists, NSO has obtained substantial funding over the last decade for several major projects (GONG, SOLIS, AO, ATST Design & Development phase, and ISOON) that service the solar community. While these projects also involve major commitments of staff time to develop and operate, NSO scientists nevertheless remain scientifically productive as documented in the NSO annual report. To support the staff scientists' research, while simultaneously contributing to the education of young scientists, NSO supports a number of graduate and undergraduate students each summer, and several during the academic year, to assist with observations and data analyses. NSO also holds one or two international workshops each year with topics that relate to staff research. These workshops are well attended (80-100 participants) and provide the NSO staff an additional chance to interact with other scientists in an informal and productive atmosphere.

V EDUCATION AND PUBLIC OUTREACH

NSO has a comprehensive public affairs and educational outreach plan that includes graduate research and training, undergraduate research, teacher research and research-to-classroom experiences, public programs, media information, elements of distance (Internet) learning, and K-12 education. A scientist at each site has responsibility for the local educational and public outreach (EPO) program, with additional support provided by other members of the scientific and administrative staff. The EPO officer for ATST now coordinates outreach activities to schools, colleges and the media for both the ATST and NSO programs. NSO wants to add an EPO position to its base program and requests incremental funding (Section V1-2.3) to support such a position.

NSO EPO goals are:

- To train the next generation of scientists and engineers through support for graduate students and postdoctoral fellows and close collaboration with universities and the ATST consortium.
- To develop K-12 teacher training and student training programs to advance knowledge of science and technology.
- To increase public understanding of the Sun, both as a star and as the driver of conditions on the Earth, as well as understanding of the related disciplines of optical engineering, electronics and computer sciences, as applied through the ATST and other NSO projects.
- To increase nationally the strength and breadth of the university community pursuing solar physics.
- To enhance the understanding and application of science and math education in our schools, colleges and the public at large, and among traditionally under-represented communities (women, Native American, African American, and Hispanic).

NSO will work with its university-based user community and the ATST consortium to support EPO on several fronts that leverage and expand existing programs within the partnering groups and create unique opportunities offered by the ATST. Many of the activities described here will be developed with an eye towards supporting both NSO and ATST educational goals.

Table V-1 summarizes the level of EPO personnel support embedded in the NSO and ATST program. In addition, NSO participates in and receives support from the NOAO Public and Educational Outreach (PAEO) office. NSO makes resources available to support its EPO effort in the form of supplies and materials, computer workstations, WWW site, housing, Visitor Center and telescope time. Including the manpower shown in Table V-1, NSO devotes about 5% of its resources to outreach.

Table V-1. Annual Educational and Public Outreach (FTEs)

Function	SRA REU RET	TL-RBSE	WWW Public Outreach	WWW Sci. Data	HS/K-12 Tasks	Public Tours	K-12 Tours	EPO Admin.	TOTAL
ATST EPO Officer	0.10		0.50		0.20			0.20	1.00
Web Master (part-time at each site)			0.60	0.20	0.00	0.20	0.10	0.10	1.20
Scientific Staff	0.50	0.10	0.10	0.20	0.10	0.10	0.10	0.10	1.30
Scientific Support Staff	0.10	0.05	0.10	0.30	0.10	0.10	0.10	0.10	0.95
Summer Students			0.20	0.00	0.10	0.20	0.20	0.00	0.70
TOTAL	0.70	0.15	1.50	0.70	0.50	0.60	0.50	0.50	5.15

1 Educational Outreach

NSO conducts several programs designed to train the next generation of solar physicists as well as introduce future taxpayers to the importance of solar physics.

Research Fellows. Although funding has limited the number of NSO postdoctoral positions, NSO continues to host several each year through grants. Several postdoctoral fellows have participated in the adaptive optics program both at NSO and NJIT. GONG has one sometimes two fellowship positions supported by NASA grants. During FY04 we plan to fill one or two fellowship positions to exploit the new high-resolution capabilities and to participate in the ATST program.

Thesis students. NSO annually hosts students working on advanced degrees. Typically, NSO staff members serve as adjunct faculty and act as the local thesis advisors. Thesis students during the past year include Michael Eydenberg (MS, New Mexico Tech), Klaus Hartkorn (PhD, NJIT), Jose Marino (PhD candidate, NJIT), Jose Ceja (MS, University of California, Northridge), and Dave Byers (PhD, Utah State University). Their work has included development of image reconstruction for AO systems, high-resolution observations of magnetic structures using adaptive optics, the development of an IR camera system, and the prediction of solar activity. Two new students will begin thesis work at the NSO in FY 2004.

REU/SRA. Since the inception of NSO in 1983, the observatory has conducted programs that offer under-graduate and graduate student research opportunities. Large fractions of active solar astronomers worldwide (as well as science/engineering leaders in other disciplines) have been alumni of the NSO summer programs. In the recent years, many of our students were drawn from universities participating in the ATST program. Primary programs are the Research Experiences for Undergraduates (REU), and Summer Research Assistant (SRA) program for graduate and non-REU undergraduate students. The annual enrollment for the REU program is 6-8 undergraduates and for the SRA program 4-6 students. These programs actively recruit minority students and women. Women have comprised 40% of the REUs and 26% of the SRAs, and minorities 5% of the two programs. During the past three years, some of these students have participated in the ATST site survey instrumentation and data analysis, adaptive optics, and high-resolution observational and theoretical projects directly bearing on ATST science to understand solar magnetism.

Teacher and Student Programs for K-12. Participation in research and training for high school teachers is provided at NSO through the Research Experience for Teachers (RET) program and the New Mexico Science, Technology, Engineering and Mathematics Talent Expansion Program (STEP). Currently, approximately four teachers participate each summer. They have worked with staff members and REU students on a variety of projects that have provided both research experience and material for classroom programs. They are given strong exposure to the NSO and ATST program. NSO also participates in the Teacher Leaders in Research Based Science Education (TLRBSE) program developed by NOAO. NSO provides teachers with hands-on observational opportunities to collect and analyze data on solar magnetism and variability. Scientists from NSO then interact with the teachers at the institute and provide research guidance throughout the year. These teachers in turn form a cadre for developing classroom programs that can be disseminated to broader audiences.

Examples of modules that were developed for younger students include the Data and Activities for Solar Learning (DASL) and Research in Active Solar Longitudes (RASL), both employing the Contemporary Laboratory Experiences in Astronomy software and the K-3 solar music educational

module from GONG data. We will build on this experience to construct modules on solar magnetism, initially based on SOLIS data and then working in ATST goals.

Project ASTRO. Project ASTRO is an educational outreach program initiated by the Astronomical Society of the Pacific to build relationships between astronomers and educators by encouraging interaction in the development and execution of astronomy activities in the classroom. NSO provides guest astronomers for the program and hosts an annual workshop for astronomers and educators.

Further Undergraduate and Graduate Outreach. NSO is investigating hosting an engineering challenge wherein college teams would be invited to design and build basic instrumentation that would be evaluated on existing NSO telescopes. The intent is to provide practical engineering experience to stimulate future candidates for REU and other advanced programs. NSO also is placing a PowerPoint lecture and resources list online for use by students in the Space Studies program at the University of North Dakota. This accompanies a colloquium lecture delivered by the EPO officer in 2003 and taped for distance students. The EPO officer and two NSO scientists will write a chapter for an advanced undergraduate book on observational astronomy.

New Programs. NSO would like to undertake three new EPO initiatives and include them as part of the EPO section of the ATST proposal. These initiatives include: Max 2008, Other Suns for Other Worlds, and The Sun on Wheels. These will be designed to complement TLRBSE and Project ASTRO as well as outreach to schools and public programs. Max 2008 will take advantage of the anticipated Cycle 24 maximum around 2007-2008, the centennial of Hale's discovery of solar magnetism, and the International Heliophysical Year. Other Suns for Other Worlds will take the natural interest in nighttime astronomy and the hunt for other planets supporting life as a means of teaching about our Sun. The Sun on Wheels will be a van equipped with telescopes, lesson plans, and other materials that can take Max 2008, Other Suns, and existing programs to schools and public events. The telescopes initially will be ATST survey telescopes adapted for public programs. Advanced imaging systems will be added as the program evolves. Funding will be sought through NSF and other organizations.

2 Other Outreach

At the Sunspot Astronomy and Visitor Center, we anticipate completion of the live solar viewer that will project a white-light image of the Sun from a heliostat outside the Visitor Center to a screen inside the center. This has been delayed by software problems. NSO is exploring a new exhibit, Ride a Magnetic Carpet, to educate visitors about the magnetic nature of the Sun. It will include a combination of computer stations with interactive graphics, hands-on units, and models of the Sun and of a sunspot. Additional exhibit materials include new display panels for the Dunn Solar Telescope lobby and the Visitor Center to highlight current observing programs at Sunspot. We also are defining a computer kiosk that would provide access to real-time imagery from ISOON and allow visitors to perform simple image manipulations through a subset of IDL routines use by the ISOON team. Both the exhibit and kiosk will be designed to be transportable so they could be used at either the Sunspot or Kitt Peak visitor centers or by other members of SCOPE. NSO will support the Franklin Institute in Philadelphia in writing a proposal for a planetarium show on the Sun and will support development if funded. NSO will exhibit again at the National Science Teachers Association annual convention and will join the Association of Science and Technology Centers. NSO is applying to join the outreach component of NASA's Living With a Star program, a broad, powerful outlet for NSO materials and messages. NSO continues to participate in the Southwestern Consortium of Observatories for Public Education

(SCOPE), a consortium of research institutions in the southwest that promote a public awareness of astronomy through access and education. We have initiated a series of public lectures with the Lodestar planetarium in Albuquerque, with the first ones scheduled for March 19 and June 22.

3 Media and Public Information

Print Products. NSO has recently released for printing a 20-page booklet describing the ATST and its science mission (Web versions are planned). New print products include a press kit on ATST (fact sheet, technical news reference, image collection), and fact sheets and trifolds on SOLIS and GONG.

Web-Based Outreach. The Ask Mr. Sunspot feature will be revamped to streamline past answers into a comprehensive set and to write new tutorials about the Sun and ATST. Web stories anticipated in FY 2004 include SOLIS becoming operational, the AO/DLSP combination at the Dunn Solar Telescope, and expansion of ISOON capabilities. Other stories will be based on observing programs at Kitt Peak and Sunspot and of science papers published by the NSO staff. With the Scientific Visualization Studio at NASA's Goddard Space Flight Center, the NSO will explore new computer visualization concepts. NSO also is developing a streamlined online catalog of solar and instrumentation images for use by the public and the media. Initial offerings will be posted in the spring.

VI MANAGEMENT AND BUDGET

1 NSO Organization

Currently, NSO is managed in three major functional units, NSO/Sacramento Peak (NSO/SP), NSO/Tucson (NSO/T), and NSO/GONG, and major project groups comprising high-order AO, SOLIS, and ATST, all of which have a mixture of NSO base and separate funding. As the separate funding for AO and SOLIS are completed this year, these programs will become part of the NSO base programs. NSO conducts operations and projects with a combination of positions funded from its base NSF support, “soft money” positions funded from projects and grants, and positions funded by its collocated partner organizations. In addition, NSO shares support personnel (e.g., shops, facilities maintenance, computing, administration) with NOAO in Tucson and on Kitt Peak. Funds for these shared services are in the NSO budget and are shown on the NSO spending plan (Section VI-2), but the funds are currently committed to NOAO for shared services, which result in considerable cost savings. Table VI-1 shows the staffing levels for all but the NOAO positions.

Table VI-1. Staffing							
	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total
Scientists	1.0	4.0	6.0	5.0	1.0	1.0	18.0
Engineering/Science Staff		7.0	5.0	7.25	5.80	3.25	28.3
Administrative Staff	1.0	5.0	1.0	2.0	3.0		12.0
Technical Staff		7.0	4.0	6.25		2.5	20.75
Maintenance & Service Staff		9.5					9.5
<i>Total Base Program</i>	2.0	32.5	16	20.5	9.8	4.25	88.55
AF Supported Science Staff		5.0					5.0
AF Supported Technical Staff		2.0					2.0
Other NSF Projects (AO, CHEM)		2.0	1.0				3.0
NJIT Postdocs, Graduate Students		2.0					2.0
NASA Supported Science Staff			2.0	3.0			5.0
NASA Supported Technical Staff			1.0				1.0
ONR Supported Science Staff			2.0				2.0
Emeritus Science Staff			2.0				2.0
Visiting Scientists		1.0	2.0				3.0
<i>Total Other Support</i>		12.0	10.0	3.0			25
Total Working at NSO	2.0	44.5	26.0	23.5	10.8	6.75	113.55

The NSO Director's office consists of two employees, the Director and an executive assistant. The Director currently resides at NSO/SP. A site director for NSO/T also serves as Deputy Director and oversees operations at Tucson. NSO/SP has a site administrator for operations and facilities. In addition, the NSO Director shares support personnel with NOAO for accounting, human resources, graphics, educational outreach, etc.

NSO/SP operates several telescopes on Sacramento Peak in New Mexico as well as office, computing, instrument development and housing facilities for visitors and the resident scientific and technical staff. Major projects at NSO/SP include development of adaptive optics, continued support of site-survey instruments for the ATST, and work on the ATST design. In addition, NSO/SP conducts experiments and minor projects to improve near-IR cameras and spectroscopy, narrow-band imaging in the visible and IR, and vector polarimetry techniques that can take advantage of high-resolution facilities.

NSO/T operates the solar telescopes on Kitt Peak, offices in Tucson, and conducts projects at the Tucson facilities. NSO shares support personnel with KPNO on Kitt Peak and with the other NOAO divisions in Tucson. Major projects at NSO/T include SOLIS, large-format IR camera development, and work on the ATST site survey and design. NSO/T also conducts experiments and minor projects to improve Stokes polarimetry techniques, imaging at the McMath-Pierce solar telescope, solar-stellar observation techniques, and speckle imaging techniques

NSO/GONG, located in Tucson, operates and maintains the GONG network of six telescopes, collects, processes and provides data to users.

A high-level organizational chart is shown in Figure VI-1. Detailed charts are shown in Appendix G. As NSO fully establishes independent operations and begins development of the ATST, the management structure will evolve over the next few years. When the ATST is completed, NSO will completely reorganize and consolidate its resources.

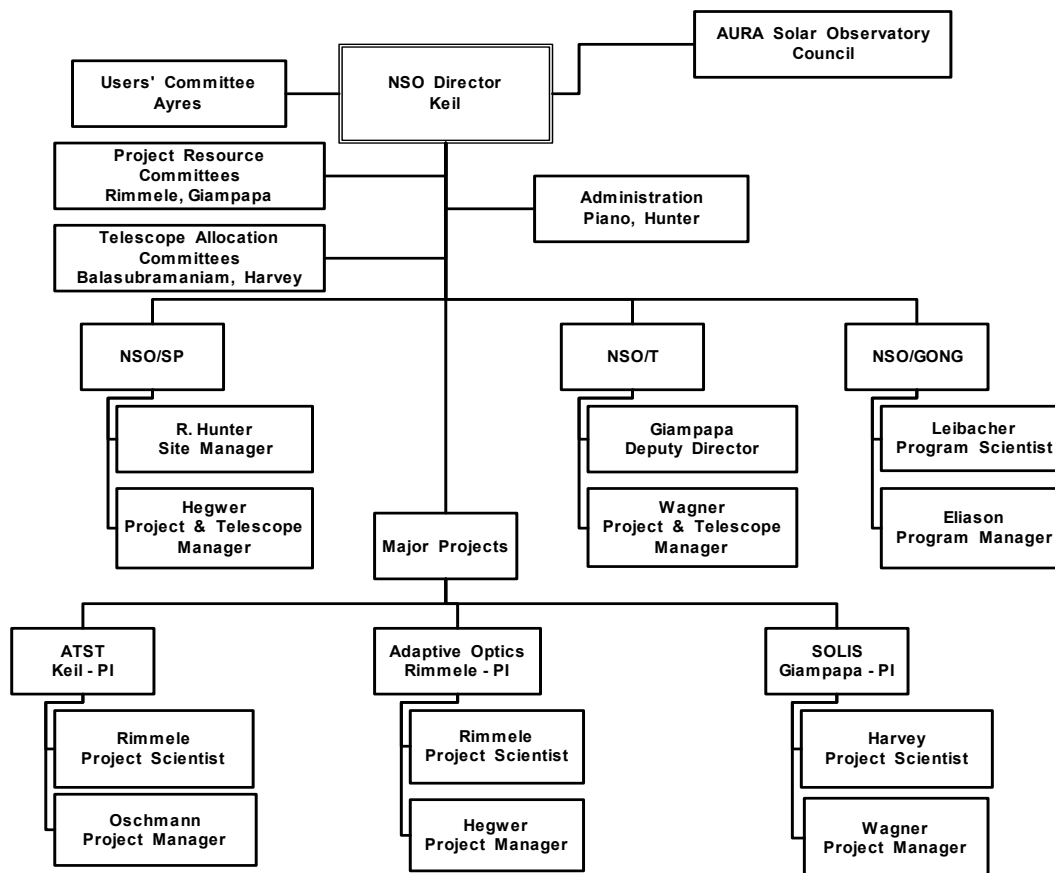


Figure VI-1. NSO High-Level Organization Chart

2 FY 2004 Spending Plan

Table VI-2 summarizes the NSO budget in FY 2004 for its current program of providing support to the US solar physics community and developing the ATST. The NSO program was developed based on receiving \$12,072K for its combined base program (Tables VI-4 through VI-9) and the ATST project (Table VI-10). In addition, we plan on receiving \$200K from the NSF Atmospheric Sciences Division to support the ATST. NSO also receives operational support from the Air Force Research Laboratory, under an MOU between the AF and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NASA provides a small amount of operational support for SOLIS (\$32K). NSO earns revenue from operation of the cafeteria, the Visitor Center, and housing on Sacramento Peak. These funds are used to support the operations that generated them.

Table VI-2. NSO FY 2004 Funding	
<i>(Dollars in Thousands)</i>	
NSF Astronomical Sciences Division Funding	\$12,072
NSF Atmospheric Sciences Division Funding	200
AFRL Support for Sac Peak Operations	450
NASA Support for Kitt Peak Operations	32
NSF REU/RET Program	80
Revenues (Housing, Kitchen, Visitor Center)	176
Total NSO Funding	\$13,010

In addition to the funds shown in Table VI-2, NSO also receives funding through a variety of grants with both NSO and non-NSO principal investigators. These funds are used to hire soft-money support personnel for specific programs, to support visiting PIs and to enhance capabilities needed for these programs. The enhanced capabilities are then normally made available to the user community. There are currently several programs that fall into this category. Funding from NASA is paying to upgrade GONG data collection to a real-time system and to enhance distribution of GONG magnetograms. A grant from NASA supports two positions to work with the global helioseismology data. NASA is also paying to collect high-resolution FTS spectra of the Earth's upper atmosphere. The Office of Naval Research (ONR) is providing support for magnetic field measurements with SOLIS (previously with the KPVT). The NSF Chemistry Division also supports a program with the FTS. Jack Eddy (Sun/Weather/Climate) and Drew Potter (Sodium Emission Lines, Near-Earth Objects, Planetary Observations) work at NSO/Tucson, supported by their own NASA grants. NSO has a NASA grant to support development of the Virtual Solar Observatory.

NSO funds are allocated to the various tasks NSO must perform to fulfill its mission (telescope operations, instrumentation, etc.) and then broken down by functional units (Sac Peak, Tucson, GONG, projects, and the Director's office) as a means of assigning responsibility and budget authority. Appendix C provides a table showing the funding cross-referenced by site and functional area. Table VI-3 summarizes the planned spending by functional unit and Figure VI-2 shows the percentage of the programming going to each area.

**Table VI-3. NSO FY 2004 Planned
Spending by Functional Area**

(Dollars in Thousands)

Director's Office ¹	\$424
AURA Corporate Fee	275
Educational & Public Outreach (EPO) ²	287
Tucson/Kitt Peak	2,031
Sacramento Peak	2,334
GONG	2,767
ATST D&D Effort	2,649
ATST Increment	1,150
ATST In-House Contribution ³	793
SOLIS	300
Total NSO Program	\$13,010

¹ Contains \$18K of programmed indirects.

² Combines the EPO funding at Sac Peak & Tucson, and EPO support received from NOAO.

³ This number represents in-house personnel working on ATST-related technology, the ATST site survey, and ATST design, and non-payroll support of these efforts.

The EPO line in Table VI-3 does not contain contributed efforts by the science staff. Although scientists spend part of their time on EPO, their salaries are contained in the Tucson, Sac Peak and GONG budgets.

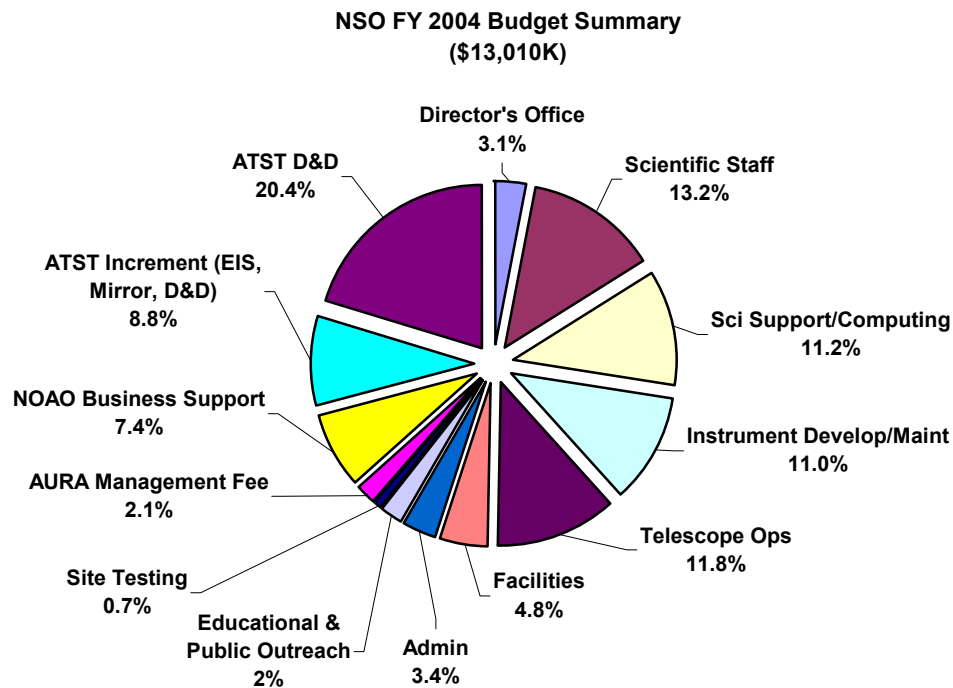


Figure VI-2.

Tables VI-4 to VI-9 break out the spending plan for the major functional units in more detail. The funding summarized on the outreach line of Table VI-2 that is spent in each location is shown at the end of each table. The outreach support received from NOAO for the programs in Tucson and at Sac Peak is shown in the table for the Director's office.

Table VI-4 presents the Director's office budget. Some of the indirect amounts earned from non-NSF funded projects are budgeted towards operation of the Director's office. Non-payroll expenses include travel, supplies and materials, and other miscellaneous expenses. Committees include the semi-annual meetings of the Users' Committee and support for other committee meetings as needed to support management of the observatory. The plan for the \$72K reserve is to provide an NSO-wide salary adjustment to bring NSO salaries in better alignment with universities.

Table VI-4. Director's Office			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Staff	286	29	315
Committees		12	12
NOAO Support	17	7	25
Reserve		72	72
Total Director's Office	\$303	\$120	\$424
Outreach Support from NOAO	81	35	115

Table VI-5 shows the budget break down for Tucson operations. The \$32K received from NASA supported the operation of the KPVT and will now support SOLIS. Most of the instrument development program will be devoted to putting the ALADDIN array infrared camera on-line.

Table VI-5. NSO/Tucson			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	720	43	762
Scientific Support/Computing	177	10	187
Instrument Development	302	47	348
NOAO ETS & IRAF Support	105	0	105
Telescope Operations	133	65	198
NOAO Support	344	86	430
Total NSO/Tucson	\$1,780	\$251	\$2,031
Outreach (REU/RET)	32	8	40

Table VI-6 breaks out the Sacramento Peak operations budget. Instrument development is concentrating on adaptive optics and upgrades to focal-plane instrumentation so users can take full advantage of diffraction-limited imaging. The Sac Peak administrative staff oversees site operations, visitor support, purchasing, shipping, receiving and budgeting. The facilities include costs for buildings (telescope facilities, offices, shops, civil engineering facilities, and administrative facilities), grounds, maintenance, utilities, housing (funding for housing support comes from rental revenues), water and sewage treatment, site snow removal and road maintenance.

Table VI-6. NSO/Sacramento Peak			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	352	36	389
Scientific Support/Computing	159	113	272
Instrument Development	407	49	456
Telescope Operations	164	26	191
Facilities	271	351	622
Administrative Services	219	24	244
NOAO Support	129	32	161
Total NSO/Sacramento Peak	\$1,702	\$632	\$2,334
Outreach (REU/RET)	92	39	132

Table VI-7 contains the \$450K contribution of the USAF as well as the revenues earned from housing, meal services, and Visitor Center sales. The USAF funding is added to the general operations funding of the NSO to offset the support given to the Air Force Research Laboratory program at Sac Peak. Table VI-7 gives a breakdown of how these funds are used to support the AFRL program.

Table VI-7. Air Force FY 2004 Funding			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Support/Computing	55	29	84
Telescope Operations	28	5	33
Instrument Development	100	25	125
Facilities	74	76	147
Administrative Services	48	10	58
Total Air Force	\$305	\$145	\$450

Table VI-8 summarizes the GONG spending plan for FY 2004. The increased cost of collecting and processing the high-resolution data is reflected in the DMAC and telescope operations budgets. Although the table does not show an outreach line, the GONG scientific staff participates in the outreach program at Tucson and receives support from the NOAO outreach line shown in the Director's office budget (Table VI-4).

Table VI-8. NSO/GONG			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	336	40	375
DMAC Operations	454	489	920
Telescope Operations	437	487	932
Administrative Services	146	34	196
NOAO Support	275	69	344
Total NSO/GONG	\$1,649	\$1,119	\$2,767

SOLIS spending, Table VI-9, will also include planned carryover (not shown) from FY 2003. This reflects SOLIS having started late in a fiscal year and the delays encountered on camera delivery from vendors. Because of a delay in the delivery of the PixelVision camera, SOLIS has implemented a contingency camera system. The carryover will support the final installation and debugging of SOLIS on Kitt Peak.

Table VI-9. NSO/SOLIS			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	83	0	83
Telescope Operations	85	132	217
Total NSO/SOLIS	\$168	\$132	\$300

2.1 ATST Program

Table VI-10 summarizes both the NSO in-house investment in the ATST and the ATST project funding NSO expects to receive in FY 2004. The NSO in-house contribution to the ATST includes development of an adaptive optics design that will be scalable to the large aperture of the ATST; investment in IR camera technologies needed to use the ATST in the 1.0- to 28-micron wavelength range; support for technical trade studies for heat control, scattered light, telescope contamination issues and off-axis design; and support for the site survey operation. Additional funding for the ATST is being provided by NSF/ATM to support HAO's participation in the project. This funding is shown separately in Table VI-11. It covers the development of an instrument design for a visible light polarimeter and participation in the design of an IR polarimeter led by the University of Hawaii.

The design and development phase of the ATST project covers five years, beginning in the last few months of 2001 and ending in 2006. The D&D phase will be followed by a six-year construction phase that is planned to begin in FY 2006. A design and proposal for the construction costs are the main products of the D&D phase. The conceptual telescope design and most of the preliminary design will be completed in-house with the collaborators providing input to the telescope design and designs for the major instruments. Detailed designs of major components will be subcontracted. Whenever cost effective, we will re-use existing optical, mechanical, and electrical designs that can meet our scientific requirements.

Table VI-10. NSO/ATST			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
<i>In-House Contribution</i>			
Science Support	100	0	100
Technical Support	160	0	160
AO	196	80	276
IR	40	40	80
Site Testing	40	50	90
ATST Fellowship	87	0	87
<i>Total In-House Contribution</i>	\$623	\$170	\$793
<i>ATST D&D Project</i>			
ATST Project Staff	1179	193	1373
Science Travel		60	60
Collaborator Awards (Design)		288	288
HAO Subcontract (ATM Funding)		196	196
Contracts		485	485
Educational Outreach	86		86
NOAO Shared Services	162		162
EIS, Mirror, Subcontracts	0	1150	1150
AURA F&A Fee @ 1.9%		74	74
<i>Total D&D Project</i>	\$1,427	\$2,446	\$3,872
Total ATST	\$2,050	\$2,616	\$4,665

Table VI-11. HAO ATST FY 2004 Spending Plan (NSF/ATM Funding)			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Visible Light Polarimeter	96	80	176
IR Polarimeter (with Hawaii)	10	10	20
Total HAO ATST Program	\$106	\$90	\$196

2.2 Funding Priorities

NSO is totally committed to developing the ATST over the next several years. In order to accomplish this while maintaining a healthy national solar research program, NSO has developed a program that generates a substantial in-house ATST investment. Ongoing telescope support and instrument projects are designed to contribute to both the scientific and technical program for the ATST. Given the need to maintain a US presence in solar physics and the goal of attaining an ATST, NSO has prioritized its efforts as follows:

1. Operate NSO flagship facilities until an Advanced Technology Solar Telescope replaces them.

Supporting US solar astronomers to obtain high-resolution observations in the visible and IR is critical if NSO expects to have users who will exploit the science capabilities of the ATST. Given that NSO facilities are still the world's best in many aspects and that we currently enjoy a lead in solar adaptive optics, IR

technology development, solar synoptic observations, and coronal spectral line observations, we should continue to utilize these strengths. To continue ATST progress, NSO will:

- Restructure base-funded project activities at NSO/SP to focus on technologies needed for the ATST. Concentrate on AO, site testing, and telescope technology testing while aggressively seeking partners and funding for these activities. Delay, or indefinitely postpone, some non-critical maintenance items.
 - Restructure base-funded activities at NSO/T not related to SOLIS development and operations in order to focus on ATST development. Concentrate on IR development and high-resolution imaging and spectroscopy in the infrared.
 - Both sites would contribute scientific staff time to ATST development (AO, IR technology, and design).
 - Activities at NSO that are supported by other agencies (NASA, AF, NOAA, etc.) will continue as long as they are fully funded.
2. Operate SOLIS by devoting NSO resources currently used to operate and reduce data from the KPVT. NASA plans to continue providing operational support and we are developing proposals to find additional support.
 3. Operate the new high-resolution version of the GONG network.

2.3 Strategic Needs

The NSO long-range plan (FY 2003-2007) contains discussions of several areas where budget increases, beyond projected inflation increases, are needed to ensure effective support for the solar community with current NSO facilities. The budget increases would also position NSO for operating its new facilities, which will require increased levels of effort because of their complexity and greatly enhanced capabilities. The requested deltas assumed that NSO would receive the revised budget awarded in the AURA Recompetition Proposal for management of NSO and NOAO (\$12,850K in FY 2004). The targeted \$12,072K is substantially lower than this amount; thus we have reworked our requests for program enhancements.

Specific areas where funding enhancements would support strategic needs (listed in priority order) include:

- An enhancement to the ATST D&D program of \$1.2M. This would provide funds to conduct environmental assessments for two potential ATST sites (Haleakala and Big Bear) and to bring the ATST funding level back near the original proposal so that the D&D phase can produce more detailed designs and better costing and have the necessary funds to begin early mirror procurement if permission is obtained.
- An enhancement of \$174K for two postdoctoral fellows to work on high-resolution observing and to interface with modelers in support of the ATST program.

- An enhancement of \$100K to increase NSO salaries, which have fallen substantially behind the university community and the other AURA centers. More competitive salaries are needed to maintain the staffing levels to meet NSO's increasing obligations. The proposed NSO-NOAO split of the President's budget will permit NSO to provide an ~3%-raise in FY 2003. According to AURA's salary survey, NSO scientific staff salaries are low by 10-20%, and technical and administrative staff salaries by 5-10%. NSO needs to address this issue, or risk losing key members of its staff.
- An enhancement of \$300K for deferred maintenance. This is about one-third of the shortfall that is needed over the next three years to upgrade and maintain NSO facilities at a level that will provide strong scientific support for the solar community and keep the US at the leading edge of solar physics. Because of limitations in resources, both NSO sites have deferred maintenance and upgrades in favor of putting NSO resources into new projects. Both the Dunn Solar Telescope (DST) and McMath-Pierce Solar Telescope need some investment in visible and IR camera systems, telescope control systems, and some critical maintenance items to keep them performing at a level needed to provide quality data to the solar community. NSO/Sac Peak needs to upgrade its sewage plant, repave some roads, repaint many of the structures, and bring housing electrical systems up to code to keep a viable infrastructure that supports the DST and other observing facilities.
- An enhancement of \$100K for Educational and Public Outreach (EPO) to support an educational outreach officer responsible for supervising and implementing the programs discussed in Section V. His/her efforts will be coordinated with the ATST EPO effort. Currently, most of the responsibility for EPO resides with the scientific and administrative staff. The EPO officer would coordinate and increase the effectiveness of staff efforts and enable the scientific staff to devote more time to research.

APPENDIX A: MILESTONES FY 2004

This section describes the major project milestones for 2004.

A1. Advanced Technology Solar Telescope

The most important goal for NSO is the construction of an Advanced Technology Solar Telescope, which will achieve high-resolution imaging (0.1 arcsec) in the optical on a regular and sustained basis. The ATST also will be capable of operating in the thermal infrared. Key activities include follow-up on recommendations from the conceptual design review (CoDR), preparation and submission of the construction phase proposal and work towards the preliminary design review (PDR) in early FY 2005. Specific milestones for the ATST and related instrumentation programs include the following:

- Submit the ATST construction proposal.
- Complete follow-up activities from the CoDR recommendations.
- Establish design contracts.
- Rework program plan based upon vendor feedback.
- Complete site testing to prepare for final site selection.
- Continue to develop funding partnerships for the construction phase.
- Hold the system-level preliminary design review in October 2004.
- Continue to develop funding partners and obtain letters of commitment for the construction phase.

A2. Solar Adaptive Optics

- Complete integration of the DLSP and high-order AO and commission it as a user instrument.
- Upgrade low-order AO to high-order AO.
- Conduct science runs with both high-order AO systems.
- Complete the development of point spread function (PSF) estimation software.
- Develop multi-conjugate AO (MCAO) wavefront sensor real-time software and control.
- Conduct MCAO engineering runs at the DST.

A3. Diffraction-Limited Spectro-Polarimeter

- Develop a user-friendly graphical user interface (GUI) for the DLSP.
- Test the performance of the DLSP for the large FOV mode.
- Integrate the DLSP camera with other instrument control computer (ICC) cameras.

A4. SOLIS

- Complete construction and testing of the ISS and FDP.
- Complete the guider.
- Develop an upgrade path for the VSM cameras.
- Move SOLIS to Kitt Peak.
- Fix initial ISS and FDP startup problems.
- Develop a viable SOLIS operations plan with constrained funding.
- Submit a plan for developing a SOLIS network through partnerships.

A5. GONG

- Continue transformation to long-term operations, with emphasis on in-house science.
- Restore the engineering site to a full-function system.
- Rebuild and re-engineer light-feeds, subsystems, and individual components as needed.
- Develop and implement a plan to build a complete spare instrument.
- Decrease time required to release data products.
- Release online version of the GONG data reduction and processing documentation.
- Fully implement the automatic image quality assessment software.
- Implement high-spherical harmonic degree global p-mode processing and local helioseismology.
- Initiate near-real time farside imaging.
- Provide near-real time magnetograms.
- Migrate the data archive to new media.

A6. Solar Infrared Program

- Remote testing of ALADDIN camera controller.
- Completion of science dewar construction.
- Integration and testing of controller, dewar and ALADDIN array.
- Initial science observations at McMP – Spectroscopy.
- Development of polarimeter interface software and observing scripts.

APPENDIX B: STATUS OF FY 2003 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2003 Program Plan. (FY 2003 milestones appear in italics below.)

B1. ATST

Complete the formation of an ATST Design Team.

The ATST project team has been hired and several NSO employees have been assigned duties within the ATST project. We will be adding one or two more as our needs evolve in 2004.

Perform the critical trade studies.

All major trades developed during 2002 have been completed as part of the conceptual design process. The off-axis concept, f ratio of the primary optics, and the enclosure concept have all been selected. Some revisions to the transfer optics and instrumentation interfacing are being worked on in response to feedback and ideas from the conceptual design review. The heat stop concept has been chosen with some continuing trades at the detailed level and development of several initial instrument concepts have begun.

Collect and analyze one year of data with the site survey telescopes.

All site testing equipment was deployed, data collected and analyzed as part of the initial down selection to the three remaining sites (BBSO, Haleakala, and La Palma). Less sky brightness data was collected than hoped, but this is a major push for continued testing of the remaining site.

Develop funding partnerships for the construction phase.

Letters of interest have been solicited as part of our construction proposal efforts from potential European partners as well as for continued NASA and Air Force Research Lab involvement.

Hold a concept design review (CoDR) in spring 2003.

The CoDR was held in August of 2003. This allowed more detailed work to be done on the enclosure trade, which was identified as the area needing the most work during a couple of workshops held during 2003.

B2. Solar Adaptive Optics

Complete opto-mechanical installation at the DST in November 2003.

The full installation was completed and debugged.

Schedule an engineering run at the DST in December 2003.

Several engineering and science runs have now produced stunning results

Begin opto-mechanical installation at BBSO in December 2003.

BBSO system was installed in December 2003.

Schedule engineering runs at BBSO and the DST from February through June 2003.

Engineering runs at Sunspot were scheduled throughout 2003. The Big Bear system was installed in December 2003 and engineering runs are now underway.

Initiate commissioning phase with science runs in July/August 2003.

Several “shared-risk” science runs were performed at the DST and produced excellent results. The NSO high-order system is operating and when the Diffraction-Limited Spectro-Polarimeter is completed it will become a dedicated user facility along with the high-order AO system.

B3. Diffraction-Limited Spectro-Polarimeter

Complete the Phase 2 design.

Construct the modulator package.

Interface the high-speed camera.

All of the above milestones were completed in October 2003. The DLSP will begin commissioning activities in early 2004.

B4. SOLIS

Complete testing at the GONG site.

Testing of the VSM was completed at the GONG site. Initial VSM operations are underway. Testing of the ISS and FDP is underway at the Tucson office building. It is planned to integrate all three instruments when the SOLIS mount and VSM are moved to Kitt Peak since there are no data recording capabilities for the ISS and FDP at the GONG site.

Complete program of cross calibration programs for ISS and VSM.

The VSM cross calibration was completed in the summer of 2003. The ISS program was delayed by a need to borrow parts of it to support the VSM. The ISS cross-calibration program may be delayed until the instrument is moved to Kitt Peak.

Move SOLIS to Kitt Peak.

Delayed. Preparation of the old KPVT building (now dubbed SOLIS Tower) is nearly complete.

Start initial operations.

The VSM is operational; the guider is not finished, so the instrument is running with ephemeris tracking and no image motion compensation or dynamic focus control. The ISS and FDP are still being tested. Major remaining elements are the optical feed head for the ISS and a guider and visible-light tunable filter for the FDP.

Fix initial startup problems.

This is an ongoing process. Most of the VSM problems have been successfully addressed. The major remaining problems are unwanted motions of two optical elements. ISS and FDP problems will be addressed when these instruments start initial operations.

Submit a plan for developing a SOLIS network through partnerships.

Delayed until it is demonstrated that SOLIS produces data of the promised quality, viable foreign partners are identified, and stable operation of the first unit is achieved.

B5. GONG

Rebuild light-feeds and other subsystems in the network instruments.

Problems with the refurbished light feed turrets have led to a thorough reassessment of limited-life issues and the development of a program of continuous renewal and improvement. To support this effort, GONG hired an engineer to restore its "ground simulator," evaluate failures, lead trouble-shooting efforts, and re-engineer as needed to assure an acceptably low downtime.

Procure remaining components and implement the GONG++ high-performance computing system.

All major components have been purchased and implemented and the system is operational.

Design and commence implementation of the GONG++ data handling system and pipeline architecture.

The data handling system, using OPUS and Veritas, is operational.

Continue development of analysis software for high- ℓ global p-mode processing, for local helioseismology applications, and for high-resolution, high-cadence magnetograms.

For local helioseismology, the merging of images, and production of ring diagram, time distance, and farside pipelines have been implemented and are operational with continuing development and acceptance testing. The high- ℓ global p-mode processing is still being developed. The magnetograms can be produced to within 1 gauss uncertainty in the zero point, but, to achieve the scientific goal of .5 gauss or better, modifications to the instrument may be needed.

Pursue funding for GONG+ near-real-time, farside imaging to maintaining a continuous stream of farside imaging data and science through the descending solar cycle...extend the useful life of SOI/MDI, prepare for the ILWS/SDO mission, support space weather forecasting.

GONG was awarded a three-year grant (January 1, 2003 through December 31, 2005, totaling \$384K) from NASA's Living With a Star Targeted Research and Technology Program to support GONG's near-real-time farside imaging project. A scientist will be hired in FY 2004.

B6. Infrared Array and Controller

Conduct acceptance tests of ALADDIN camera controller and initial dewar. These tests will include spectroscopy at 1083 nm (He I) and 4667 nm (CO molecule) and spectropolarimetry at 1565 nm (Fe I).

The camera controller is complete but still at Mauna Kea Infrared (MKIR), and the science dewar with initial optics has passed the final design and is proceeding to construction phase. The idea of running the camera with an initial liquid-helium-cooled dewar has been abandoned in favor of the purchase of a science dewar with simple optics.

Conduct initial observations as a facility instrument. The ALADDIN system will be open for shared-risk observations for six months during FY 2003 by NSO users. At least four user observing runs will be planned.

No observing runs were done in 2003.

Develop science-grade dewar specifications. Requirements for the permanent closed-cycle cooled ALADDIN dewar will be written and a strategy to fund the purchase will be developed.

The science dewar has been designed with closed-cycle cooling and is proceeding to the construction phase. This is the main development for 2003; a lower-cost science dewar with space for future optics upgrades was designed and funds secured for purchase from MKIR. This jump to the science dewar has, however, pushed the delivery schedule for the camera back approximately 18 months from the planned late-2002 delivery. The "final" optics, which will include approximately a two-to-one demagnification, have been designed but are currently on-hold. The science dewar will initially contain a filter wheel and fold mirror to feed the array directly from the spectrograph focus.

Develop the polarimeter. Current polarimeter hardware will be tested and new hardware may be purchased if needed for polarimetry in the 1000-2300 nm wavelength range. Initial tests of polarimetry in the 3000-5000 nm range will be done and specifications for a user polarimeter in this range will be written.

The CSUN/NSO polarimeter has been tested from 1083 to 2231 nm and has produced science data with published results. The NSO polarimeter components from NIM have been tested and will be used as part of the ALADDIN polarimeter system, which will basically be a copy of the working CSUN/NSO polarimeter. No tests or design work for a 3000-5000 nm polarimeter have yet been done.

APPENDIX C: NSO FY 2004 BUDGET & STAFFING SUMMARY

NSO FY 2004 Budget Summary

	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total Budget
Director's Office	398,980						398,980
Scientific Staff		388,677	762,267	375,012	187,000		1,712,956
Scientific Support/Computing		271,829	187,285	920,529		82,812	1,462,454
Instrument Development/Maintenance		456,452	453,446	-	516,000		1,425,898
Telescope Operations		190,587	198,132	931,638		217,188	1,537,545
Facilities		621,780					621,780
Administrative Support		243,771		195,869			439,640
Educational & Public Outreach	115,000	131,637	40,000				286,637
ATST Site Testing					90,000		90,000
NOAO Business Support	24,765	161,268	430,047	344,037			960,117
ATST Increment (EIS, Mirror, D&D)					1,149,732		1,149,732
ATST D&D					2,648,700		2,648,700
AURA Management Fee	201,600				73,568		275,168
Program Total	740,345	2,466,000	2,071,177	2,767,085	4,665,000	300,000	13,009,607
Revenues							
NSF ATST D&D from ATM Division					(200,000)		(200,000)
Programmed Indirects	(17,887)						(17,887)
Housing Revenue		(91,000)					(91,000)
Meal Revenue		(16,720)					(16,720)
NSF REU/RET Funding		(40,000)	(40,000)				(80,000)
AF Support		(450,000)					(450,000)
NASA Support			(32,000)				(32,000)
Visitor Center Revenue		(50,000)					(50,000)
NSF Astronomy Funding	722,458	1,818,280	1,999,177	2,767,085	4,465,000	300,000	12,072,000
Requested Deltas							
ATST EIS & Mirror Procurement	1,200,000						
NSO Salary Adjustments	100,000						
Postdoctoral Fellowships	174,000						
Deferred Maintenance/Upgrades	300,000						
EPO Position	100,000						
	1,874,000						

FY 2004 STAFFING SCHEDULE (In Full-Time Equivalents)

	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total
Scientists	1.00	4.00	6.00	5.00	1.00	1.00	18.00
Engineering/Scientific Programmers		7.00	5.00	7.25	5.80	3.25	28.30
Administrative Staff	1.00	5.00	1.00	2.00	3.00		12.00
Technical Staff		7.00	4.00	6.25	1.00	2.50	20.75
Maintenance & Service Staff		9.50					9.50
Total Base Program	2.00	32.50	16.00	20.50	10.80	6.75	88.55
AF Supported Science Staff		5.00					5.00
AF Supported Technical Staff		2.00					2.00
Other NSF Projects (AO, Chem)		2.00	1.00				3.00
NJIT Staff (Postdoc, Graduate Student)		2.00					2.00
NASA Supported Science Staff			2.00	3.00			5.00
NASA Technical Staff			1.00				1.00
ONR Supported Science Staff			2.00				2.00
Emeritus			2.00				2.00
Visiting Scientists		1.00	2.00				
Totals Working at NSO	2.00	44.50	26.00	23.50	10.80	6.75	110.55

APPENDIX D: SCIENTIFIC STAFF RESEARCH AND SERVICE

Karatholuvu R. Balasubramaniam, Associate Astronomer

Areas of Interest

Solar Magnetic Fields and Activity Evolution, High-Resolution Solar Physics, Stokes Polarimetry, Advanced Technology Solar Telescope Technical Issues, Stokes Polarimetry, Solar Mass Ejections, Near-IR Magnetometry, Space Weather, Educational Outreach

Future Research Plans

The research interests of K. S. Balasubramaniam (Bala) include understanding and modeling of physical processes in the solar atmosphere, and the role they play in solar activity. He will focus on acquiring and analyzing high-resolution dynamical solar activity data using the Dunn Solar Telescope. He will use adaptive optics and several focal-plane instruments, including HAO's Advanced Stokes Polarimeter (ASP), tunable narrow-band filters, and spectrographs for this purpose.

Research Thrust Areas and Recent Research Results

1. Understanding the influence of magnetic fields on chromospheric spectral line formation. Using data from the ASP and NSO Dunn Solar Telescope Bala is seeking ways to improve the interpretation of chromospheric Stokes spectral lines and radiative transfer modeling of chromospheric spectral lines, Bala is working with NSO colleague H. Uitenbroek, New Mexico Tech MS Student M. Eydenberg and THEMIS scientist Arturo Lopez-Ariste to exploit the Principal Component Analysis techniques to infer magnetic fields and thermodynamic parameters of the spectral line forming region.

2. Structure of Sunspots. (a) Bala is working on understanding the thermal and magnetic structure of sunspots using the dual-Fabry Perot (FP) imaging filtergraph. He is comparing the various methods of inferring the thermo-dynamical nature of sunspots, including spectral line bisector analysis, and fitting functions to spectral lines. (b) Chromospheric super-penumbral structure. Collaborating with A. Pevtsov and J Rogers (Cloudcroft Schools), Bala is working on developing a statistical structure of sunspot super-penumbrae from a large historical data set of H-alpha observations of the chromospheric superpenumbrae. The results will reflect on the helicity and the nature of twist in superpenumbrae which in turn will be useful in constructing MHD models of an extended sunspot. (c) Using high-resolution imaging at the DST, as well as Stokes spectropolarimetry from the ASP, Bala is working on understanding the dynamic structure of sunspots in the photosphere and the chromosphere. The magnetic structure of sunspot penumbra and superpenumbrae in the chromosphere, as well as its evolutionary nature is not a well understood problem. The manifestations of the inverse Evershed effect and its relationship to the observed chromospheric magnetic fields is still a challenging problem and Bala hopes to address these issues using these data. (d) In collaboration with A. Cacciani (U. Rome), Bala and A. Pevtsov intend to use the magneto-optic filter to investigate and seek signatures of Alfvén waves in the chromosphere.

3. Solar Activity. (a) Bala, S. L. Keil and C. Watts (New Mexico Tech) will embark on a project to understand the magnetic structure and dynamics of photospheric and chromospheric plage regions in an effort to understand the sustained heating structure of these regions. They will seek to verify theoretical results that the heating is due to Alfvén waves. An elaborate experiment to use the ASP and simultaneous chromospheric spectroscopy is being planned for the Jan-Mar 2004 quarter. (b) Bala is collaborating with D. Byers (Utah State) in attempting to understand the energy release process in solar flares and solar mass ejections. (c) Bala will continue to work on the goal of understanding high-resolution structure of active region filaments and

related activity to flares. He is collaborating with T. Kucera (NASA/GSFC) on joint ground- and space-based investigations of filaments using both SOHO and TRACE.

4. ATST. (a) Imaging Narrow-Band Filter. Working with G.A. Gary (NASA/MSFC) and M. Sigwarth (KIS), Bala will continue to exploit observing techniques and the importance of filter imaging with dual-FP and triple-FP cascaded Fabry-Perot Etalons.

5. In collaboration with H. Uitenbroek, Bala is planning to make measurements of polarimetry due to molecular lines in the G-Band, as predicted by radiative transfer models.

6. In collaboration with D. Neidig and A. Pevtsov and researchers elsewhere, Bala is attempting to understand the factors leading to large-scale, low-intensity chromospheric eruptions that are accompanied by filament eruptions, distantly connected flares, as well as mass ejections.

Service

Bala is chair of the NSO/SP telescope allocation committee and advises non-NSO users on observing at NSO/SP facilities. He takes lead responsibility for the NSF-sponsored REU/RET and NSO/SRA programs at NSO/Sac Peak and chairs these programs for NSO. Bala is also a prime point-of-contact for public outreach questions on astronomy and conducts public observatory tours from time to time. He participates in aspects of the observatory planning and recruiting process, serves as a project lead in developing the dual-FP system, and participates in the planning requirements for the ATST. Bala makes regular contributions to community processes such as proposal evaluations at NSF and NASA, and serves as a referee for papers in the *Astrophysical Journal*, *Astronomy and Astrophysics*, and *Bulletin of the Astronomical Society of India*. He also helps in chairing scientific sessions at meetings. Bala is the research advisor for two PhD students from Utah State University and a PhD student from New Mexico Tech.

Michael Dulick, Assistant Scientist

Areas of Interest

Molecular Spectroscopy, High-Resolution Fourier Transform Spectrometry, Study of Molecules of Astrophysical Interest

Future Research Plans

Dulick plans to continue using the McMath FTS to record laboratory spectra of diatomics in the infrared and visible to aid in the assignment of sunspot spectra. A significant portion of the analysis will entail the development of an effective internuclear potential model for the electronic states of transition-metal diatomics in order to utilize information derived from low-temperature laboratory spectra in predicting the high-temperature spectra of sunspots. Dulick will also continue to participate in projects to upgrade the detectors and data collection system for the FTS.

Service

Dulick serves as the NSO FTS Instrument Scientist for visiting investigators funded under the NSF Chemistry grant for Laboratory Fourier Transform Spectroscopy, with specific duties that include providing assistance in the experimental design and setup and the instructional use of the instrument.

Mark S. Giampapa, Astronomer

Areas of Interest

Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

Recent Research Results

Giampapa recently completed the data reduction and calibration for a survey of chromospheric Ca II H and K line emission and its variability during 1997-2001 in solar counterparts in the solar-age and solar-metallicity open cluster M67, using the WIYN telescope with the Hydra multiobject spectrograph on Kitt Peak. The results indicate the range of potential amplitudes of the solar cycle through observations of about 100 Sun-like stars. This is critical to know in view of the impact of solar variations on long-term global climate changes. One surprising result of this work was the discovery of solar-type stars that are noticeably more active than the Sun as seen at solar maximum. This may indicate that the potential excursion in the solar cycle is greater than seen so far in contemporary measurements, or that these particular M67 stars are rotating more rapidly, which would be unusual for a cluster of this age. Giampapa and T. Simon (U. of Hawaii) have received an allocation of Keck/HIRES time to measure projected rotation velocities of solar-type stars in M67. The survey and variability results will be submitted for publication in FY 2004.

Future Research Plans

Giampapa intends to continue working on the M67 project but now within the context of the recently approved, joint University of Arizona/NOAO NASA Astrobiology program. Giampapa is a Co-Investigator in this program where his efforts will focus on delineating the nature and evolution of the variable activity of solar-type stars that may be the hosts of extrasolar planetary systems. Specifically, Giampapa and his collaborators will examine the joint variation of irradiance and chromospheric (magnetic) activity in Sun-like stars in clusters ranging in age from ~100 Myr (e.g., the Pleiades) to solar age (e.g., M67 and possibly older clusters) in order to characterize the ambient radiative and deduced particle environments within which the evolution of planetary atmospheres occurs. Giampapa will utilize automated photometric systems along with moderate-large aperture telescopes to obtain both spectroscopic chromospheric data and information on associated brightness changes in solar-type stars. During FY 2004, Giampapa will hire a postdoc under the auspices of the Astrobiology program to collaborate in this effort.

M. Giampapa and V. Andretta (U. Naples) are completing the analysis on a unique data set of simultaneous He I spectroscopic observations of solar-type stars at 587.6 nm and 1083 nm, respectively. They have developed a technique to estimate active region area coverage on Sun-like stars based on these high-excitation, chromospheric diagnostics.

Finally, Giampapa will be delivering a series of lectures as part of the 2004 “Saas-Fee” in Davos, Switzerland. The Swiss Astronomical Society sponsors this intensive short course intended for postdocs and graduate students. This year’s topic is “The Sun, Solar Analogues, and Climate.”

Service

M. Giampapa serves as the Deputy Director for the National Solar Observatory, with specific responsibility for the Tucson/Kitt Peak program. In this role, he has overview responsibilities for the scientific and instrument development activities at NSO/Kitt Peak, including the SOLIS project, and the conduct and support for observing programs at the NSO McMath-Pierce Solar Telescope Facility on Kitt Peak. Giampapa is the PI for SOLIS as well as the Instrument Scientist for the SOLIS Integrated Sunlight Spectrometer (ISS); chairman of the Tucson site Project Review Committee (PRC) and serves as a member of the full NSO PRC; and, Program Scientist for the McMath-Pierce nighttime program, which is currently operated with grant funds contributed by principal investigators. As NSO Deputy Director, Giampapa assists the NSO Director in the development of program plans and budgets, including budgetary decisions and their implementation.

Giampapa is an Adjunct Astronomer at the University of Arizona. He also serves as an editorial board member for *New Astronomy Reviews*.

John W. Harvey, Astronomer

Areas of Interest

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results

During FY 2003, J. Harvey concentrated on SOLIS, the closure of the Kitt Peak Vacuum Telescope, instrumental issues associated with the upgrade of GONG, and preparing proposals for the support of SOLIS operations. This left no time for research.

Future Research Plans

During FY 2004, J. Harvey will continue to concentrate on completion of the SOLIS project and GONG instrument improvements and, consequently, it is again unlikely that any significant research will be accomplished.

Service

J. Harvey performs observatory service as Chair of the NSO/KP TAC and NSO Scientific Personnel Committee, Instrument Scientist for the GONG project, Telescope Scientist for the KP Vacuum Telescope, and Project Scientist for the SOLIS project. He is co-Editor of the journal *Solar Physics*. He serves on the SPD Hale Prize Nomination Committee and on the National Research Council Associateship Review Panel.

Carl J. Henney, Associate Scientist

Areas of Interest

Solar MHD, Polarimetry, Space Weather Forecasting, Solar Activity Cycles, Solar Evolution, Helioseismology

Recent Research Results

During the past year Henney has worked on the calibration of solar activity forecast maps. These data products, currently using KPVT synoptic data, include previously developed surface maps of magnetic field complexity, flux change, high-speed solar wind sources, and a new 1083 nm equivalent width change map. Calibration work has begun in the comparison of various morphological parameters of magnetic complexity data with the Space Environment Center's solar events. More specifically, all M1 or greater flare events are parsed from the SEC events list, and then data values from the relevant regions, for observations before and after events, are compared. Preliminary results are mixed with regards to using only one or two of these parameters for forecasting. The magnetic high-complexity perimeter parameter with the magnetic complexity spatial-gradient may be useful for selecting regions that are unlikely to flare within the next 72 hours, for example. Henney also continued collaboration with L. Bertello, F. Varadi and R. Ulrich of UCLA along with R. Garcia of CEA/DSM/DAPNIA, in the analysis of low frequency p-modes using the GOLF and MDI velocity time series.

Future Research Plans

The primary research tasks for Henney include the calibration of the VSM instrument, vector analysis, and cross-calibration of synoptic products with the KPVT. In addition, Henney will continue to calibrate the solar activity forecasting parameters with past flare and CME events. The next steps are to include parameter values from non-event active regions and to include more traditional parameters, e.g., change in the net flux, to ultimately build an event likelihood table.

Service

As Facility Scientist for the SOLIS project, Henney continued worked on the development of C based data reduction procedures for the Data Handling System (DHS) during the past year. He integrated the HAO Stokes inversion code into the SOLIS-VSM DHS for use as the VSM "Quick-look" and final inversion procedures. He also implemented proxy-KPVT (Kitt Peak Vacuum Telescope) calibration and processing algorithms for 1083 nm intensity products. In addition, he continued to develop and maintain the data reduction procedures for the production of SOLIS-VSM 630 and 854 nm longitudinal data products. He also worked on the development and implementation of the algorithms to apply geometric corrections to the VSM data products. This included the development, implementation and testing of ephemeris and spatial interpolation functions. In addition, Henney continued to maintain the synoptic data pipeline for the KPVT and to modify the KPVT synoptic data reduction pipeline to process future VSM synoptic data as part of the SOLIS DHS.

Additionally, Henney continued collaboration with F. Hill and H. Jones in the development of the "Researching Active Solar Longitudes" (RASL) educational research project. During the past year, 16 students (from two different schools) have participated in the RASL project by submitting over 2000 measurements of active region positions and areas. Henney also worked with the high school teacher Travis Stagg from Fairbanks, AK to develop a pretest and post-test to measure the subject material retention of future student participants. In addition, the RASL project was presented to TLRBSE (Teacher Leaders Research Based Science Education) participants in July 2003.

Frank Hill, Sr. Scientist

Areas of Interest

Helioseismology, Asteroseismology, Fluid Dynamics of the Solar Convection Zone, the Solar Activity Cycle, Virtual Observatories

Recent Research Results

Hill continues to perform research in helioseismology. Recent work with R. Howe, R. Komm and others has provided new information on the fluid dynamics of the outer solar convection zone. Using horizontal flows as a function of depth and position inferred from GONG and MDI data, Hill and co-workers computed vertical velocities using the continuity equation and the horizontal divergence of the flows. They found that downflows in the outer 8 Mm coincide with surface active regions, but these change to upflows below 8 Mm. These results are also found in time-distance results. Hill and co-workers also used ring diagrams to study the spatial variation of oscillation amplitudes and life times across the solar surface. They found that active regions decrease the amplitude and life time of modes with temporal frequencies below the atmospheric acoustic cut-off, but increase both parameters at higher frequencies. These effects presumably are related to the changes in the atmospheric structure created by the presence of magnetic fields. Finally, Hill and C. Barban performed the first large-scale analysis of global solar oscillations with a new method that simultaneously fits observations in intensity and Doppler velocity. This research produced the first measurements of various phase relationships and background amplitudes that can be used to test models of the mode excitation mechanism.

Future Research Plans

Hill plans to probe the lower convection zone with large-aperture ring diagrams. These studies will be used to search for longitudinal structure of the tachocline, the region of the solar interior where the rotation profile changes from differential to solid-body. In addition, Hill will begin work on a direct 3-dimensional inversion of ring diagrams to estimate the vertical and horizontal flow fields in a self-consistent way.

Service

Hill is the ATST site survey scientist and is comparing the current results with in-situ measurements of thermal fluctuations. He serves as the GONG Data Scientist, developing algorithms for the reduction and analysis of data for helioseismology. Hill serves as the NSO Digital Library Scientist, placing NSO and SOLIS data on-line and accessible over the Internet. He is participating in the development of the Virtual Solar Observatory (VSO), which was recently released to the public. He is also taking part in the European Grid of Solar Observations (EGSO) and Collaborative Sun-Earth Connection (CoSEC) projects. Hill typically supervises several staff, currently three scientists and one programmer. He is a member of the IAU Working Group on International Data Access, and the NSO/Tucson Telescope Allocation Committee.

Rachel Howe, Associate Scientist

Areas of Interest

Helioseismology, The Solar Activity Cycle, Peak Fitting

Recent Research Results

Earlier in 2003, R. Howe published papers on comparisons of low-degree mode parameters from GONG and BiSON, in collaboration with W. Chaplin (U. Birmingham, UK), and the mode frequencies from GONG and MDI, in collaboration with S. Basu (Yale), M. J. Thompson (Imperial College), J. Christensen-Dalsgaard (Aarhus, Denmark) and others, and with R. Komm and B. Durney on temporal variations in the solar angular momentum.

With R. Komm and F. Hill, and with D. Haber and B. Hindman (U. Colorado) R. Howe has been studying the variation of mode frequencies, widths and amplitudes with magnetic index in GONG and MDI local helioseismic data. The width and amplitudes results have been written up in an article that has been submitted to ApJ and is currently being revised; the frequency results will be written up separately. With F. Hill and I. Gonzalez-Hernandez, Howe has also been working on the generation of artificial data for local helioseismology, which will be shared with the community via the 'LoHCo' [Local Helioseismology Comparison] collaboration.

Howe is currently working with various members of the GONG team on possible innovative uses for GONG data, such as tracking the development of active regions in simultaneous magnetic and acoustic observations and the detection of white light flares in intensity and magnetic data.

Future Research Plans

Howe intends to continue working on the above areas and also on the temporal variation of the solar rotation.

Service

In addition to the research activities described above, Howe shares with R. Komm the (informal) responsibility for checking the results of both the GONG PEAKFIND analysis and the 'ring diagram' pipeline that is currently under development.

Sankarasubramanian Kasiviwanathan, Research Associate

Areas of Interest:

Solar Magnetic Field Measurements, Vector Polarimetry: Techniques, Study of Velocity and Velocity Gradients in and Around Magnetic Field, Inversion techniques, Image Processing Using Wavelet and Other Transforms, High-Resolution Imaging and Polarimetry.

Recent Research Results

Sankarasubramanian Kasiviswanathan (Sankar) is involved in the development of a new spectro-polarimeter, called the Diffraction-Limited Spectro-Polarimeter (DLSP), for the Dunn Solar Telescope (DST) at Sunspot, NM. This is a collaborative project between NSO and HAO. Sankar is the principle investigator (PI) for this project from NSO along with Bruce Lites as the PI from HAO. Sankar has developed a new modulator for the DLSP. The DLSP is expected to achieve the DST's diffraction limited spatial resolution in the vector magnetic field measurements. Sankar also works on the data analysis part of the DLSP as well as data from the Advanced Stokes Polarimeter (ASP). He has observed and studied the magnetic and velocity field patterns of different active regions with the best spatial resolution that can be achieved with the ASP and the low-order AO system at the DST. He has observed and confirmed the circular convective velocity pattern around solar pores seen in the numerical simulations of small-scale magnetic fields. Sankar also works on the different inversion routines and retrieving the height variations of the physical parameters from the observed Stokes spectra.

Future Research Plans

With the DLSP and high-order AO system developed at the DST, observations will be carried out to achieve the highest possible spatial resolution in the vector magnetic field measurements. There is also an effort to get involved with IR spectro-polarimetry with a simple spectrograph as well as with a fiber fed spectrograph. He is also working getting simultaneous magnetic field observations in the optical as well as in the IR wavelength. Sankar is also developing a novel technique to observe line-of-sight magnetograms over a range of visible wavelengths without the influence of the telescope polarization.

Service

Sankar is one of the principal organizers of the 2004 NSO Workshop on “Large-Scale Structures and Their Role in Solar Activity” to be held at Sac Peak on October 18-22, 2004. He was a mentor to one of the Summer 2003 REU students.

Stephen L. Keil, NSO Director

Areas of Interest

Solar Activity and Variability, Astronomical Instrumentation, Solar Convection and Magnetism, Educational Outreach, the Advanced Technology Solar Telescope

Recent Research Results

Keil is collecting high-resolution measurements of solar granulation in quiet and active areas of the solar disk once or twice each year as part of a collaborative program led by Thierry Roudier. The goal is to look for changes in convective motions that follow the solar cycle. Once reduced, the data will be added to an archive, which includes data from several ground-based observatories.

Future Research Plans

Keil is leading efforts to define an advanced high-resolution solar telescope. He will continue working on surface motions as precursors to solar activity and attempt to quantify the results. He will also continue investigating changes in chromospheric emissions through measurements of the Ca II K-line in both integrated flux and spatially resolved spectroheliograms. This work is part of a program to understand variations of the solar ultraviolet and extreme ultraviolet flux as inputs to the terrestrial atmosphere.

Service

Keil is Director of the National Solar Observatory and a member of the High Altitude Observatory advisory panel. He supervises both graduate and undergraduate students conducting research programs during the summer, and works closely with NSO and NOAO educational outreach programs.

Christoph U. Keller, Associate Astronomer

Areas of Interest

Solar Magnetic Fields, Analysis of Numerical MHD Simulations, High-Precision Polarimetry, Image Reconstruction Techniques, Active and Adaptive Optics, Telescope and Instrument Design

Recent Research Results

The new adaptive optics system at the McMath-Pierce telescope has allowed novel measurements of infrared spectral lines. In particular, we were able to record simultaneously spectral lines formed in the photosphere, above the temperature minimum region, and in the chromosphere at a spatial resolution close to the diffraction limit of the 1.5-m telescope. These observations will help find the origin of the spatial variation of the CO absorption on the solar disk.

Analyses of numerical MHD simulations of the magnetized photosphere made it clear that our traditional ways of analyzing polarized spectra are inadequate once we reach a spatial resolution comparable to the photon free-mean path and the vertical pressure scale height. New methods are currently under development.

Future Research Plans

Keller will spend almost all of FY 2004 on sabbatical, concentrating on the analysis of MHD simulations and the very exciting, first science data from SOLIS.

Service

Keller is the telescope scientist for the McMath-Pierce telescope. He is the lead scientist for the real-time soft-ware and hardware efforts for SOLIS and leads the vector spectromagnetograph (VSM) effort. He is engaged in various ATST activities and is the NSO representative on the Frequency Agile Solar Radio telescope (FASR) project. Keller is a member of the local and joint-site project review committees.

Rudolf W. Komm, Associate Scientist

Areas of Interest

Helioseismology, Dynamics of the Solar Convection Zone, Solar Activity Cycle, Dynamics of the Photosphere

Recent Research Results

Komm continues to perform research in helioseismology. He is deriving solar sub-surface fluid dynamics descriptors from GONG data analyzed with a ring-diagram technique (in collaboration with I Gonzalez-Hernandez, F. Hill, R. Howe, and C. Toner). Using these descriptors, he was able to derive, for example, the vertical velocity component of solar sub-surface flows. He is working with F. Hill and R. Howe on the variation of mode width and amplitude, which provide information about mode damping and excitation. He is also studying the relation between solar oscillations, granulation, and magnetic activity (in collaboration with Victoria Ashley, an REU summer student he mentored in 2003).

Future Research Plans

Komm will continue to explore the dynamics of the near surface layers and the interaction between flows and magnetic flux by deriving fluid dynamics descriptors from ring-diagram data. He will continue studies of the solar cycle variation of mode parameters of solar oscillations with the focus on the mode background amplitude and other indicators of mode physics. He will continue to study advanced time-series analysis techniques such as empirical mode decomposition and Hilbert transform (in collaboration with M. Roth, Freiburg, Germany) in order to evaluate their usefulness for helioseismology. With these techniques, Komm

will study in greater detail the relation between p-mode energy and magnetic activity. He will continue to study the relation between solar oscillations, granulation, and magnetic activity.

Service

Komm continues as a participant in Project ATSTRO.

John W. Leibacher, Astronomer

Areas of Interest

Helioseismology, Atmospheric Dynamics

Recent Research Results

The results from GONG are beginning to emerge, ranging from the thermodynamics and kinematic structure of the solar interior, to the effect of spatial inhomogeneities on the p-modes, to the atmospheric response of the resonant and non-resonant sound waves.

Future Research Plans

Leibacher will be devoting the majority of his efforts to assuring GONG's technical and scientific success. He will also continue work on techniques of time series analysis and chromospheric oscillations. Ideas about the observational signature of the convective excitation of p-mode oscillations will be pursued with data from GONG as well as the SOI/MDI instrument onboard the SoHO spacecraft.

Service

Leibacher serves as the Director of the Global Oscillation Network Group program. He has been a mentor to an undergraduate physics student for the past two summers. He is an IAU Joint Discussion organizer, serves on the editorial board and is Topical Issue editor of the journal *Solar Physics*, and chairs the AAS Solar Physics Division.

Matthew J. Penn, Associate Astronomer

Areas of Interest

Solar Atmosphere, Oscillations, Spectropolarimetry, Near-IR Instrumentation

Recent Research Results

Penn published two papers in *Solar Physics* and one in *ApJ Letters* in 2003, following one paper each in *Solar Physics* and *ApJ Letters* in 2002; all publications were results of spectroscopic observations of the Sun at infrared wavelengths. Two of the *Solar Physics* papers involved work with either California State University, Northridge (CSUN) undergraduate students or a summer REU student. In one of the *ApJ Letters* papers, Penn, with W. Cao (NJIT), S. Walton and G. Chapman (CSUN) and W. Livingston (NSO), discovered that a molecular absorption line from CN reveals rapid Evershed Doppler shifts in sunspot penumbra, with velocities larger than those seen in atomic spectral lines.

Papers describing the results from spectropolarimetric observations of Mercury have been submitted to *ApJ* and *ApJ Letters*, and papers describing results from the sky brightness monitor data from the ATST site survey are either submitted or in preparation. Work with the ATST site survey Sky Brightness Monitor (SBM) data analysis was carried out with two University of Arizona undergraduate students.

Future Research Plans

Penn is currently involved in the analysis of spectropolarimetric observations of sunspots at 1565 nm with a summer REU student from the University of Arizona who is working part-time at the NSO. Future plans

include use of the NSO/Sac Peak AO system for IR imaging, tests of the IR Fabry-Perot system at NSO/Kitt Peak, and investigations of 3-5-micron polarimeter packages for use with future IR camera systems.

Service

Penn has completed the tasks assigned to the ATST Coronal Working Group, and a draft of the working group report is being modified for publication. He analyzed the ATST Sky Brightness Monitor site survey data for the ATST Site Survey Working Group, and two papers describing those results are near completion. Penn has worked with the University of Hawaii IfA group in the development of the ATST near-IR spectropolarimeter instrument and continues this work.

Penn has been working on the NSO Array Camera (NAC) project; the NAC electronics package is near the acceptance testing stage, and the NAC camera dewar system has been designed and is entering the construction phase. The camera is slated to begin use in early 2004 at NSO/Kitt Peak.

Penn is in charge of the NSO/Tucson summer REU program and works closely with the NSO staff to maintain the high quality of the NSO REU program.

Alexei A. Pevtsov, Associate Astronomer

Areas of Interest

Solar Magnetic Fields: Topology, Evolution, Helicity; X-ray Corona: Coronal Heating, X-ray Bright Points; Sunspots: Topology, Evolution, Evershed Flow, Helicity, Penumbra Fine Structure, Vector Polarimetry; Space Weather: Solar Drivers

Recent Research Results

A. Pevtsov worked with researchers from other institutions on several studies including evolution of helicity in emerging active regions, chirality of chromospheric filaments, correlation between coronal and photospheric electric currents, role of kink instability in solar coronal eruptions, and magnetic field topology and flows at flux cancellation sites

Study of six emerging active regions showed that magnetic field emerges without significant twist. As an active region grows, twist increases and reaches a plateau within approximately one day of emergence. The inferred helicity transport rate is larger than differential rotation could produce. The observed time-history of twist and polarity separation were fitted by the Longcope and Welsch (2000) model, and sub-photospheric Alfvén speed was estimated from the fitting.

Chirality of chromospheric filaments was studied using H-alpha full-disk images from Big Bear Solar Observatory and NSO/Kitt Peak daily magnetograms from 2000-2001. The results confirmed the presence of the hemispheric helicity rule in quiescent filaments. It had been shown that active region filaments also follow the same rule. A possible change in the hemispheric rule with polarity reversal of the polar field was investigated, and no such change was found.

Pevtsov and his colleagues used NSO/KP full disk magnetograms and coronal X-ray images from the Yohkoh SXT telescope to determine the linear force-free field that gives the best visual fit to the most distinct coronal X-ray features of 34 active regions. In most cases, the single-alpha force-free field represents well the coronal structure. The force-free field alpha-coefficient was computed for 24 regions using vector magnetograms from the Haleakala Stokes Polarimeter. A good correlation between coronal and photospheric alpha was found. It was concluded that the electric currents in the studied active regions are of sub-photospheric origin and pass without significant modification through the photosphere into the corona.

To understand the role of kink instability in solar eruption, Pevtsov and his colleagues studied the relationship between magnetic fluxes, total electric currents and force-free-field alpha-coefficients for twelve magnetic clouds (MCs) and their associated active regions (ARs). They found that MCs and ARs have comparable magnetic fluxes, electric currents in MCs are significantly smaller than those in ARs, and the values of total twist of magnetic field in MCs are typically an order of magnitude greater than those of ARs. No systematic sign or amplitude relationship between total twist in MCs and ARs was found. Based on these findings, they concluded that magnetic clouds associated with active region eruptions are formed by magnetic reconnection between these regions and their larger-scale surroundings, rather than the simple eruption of pre-existing structures in the corona or chromosphere.

Using high-resolution vector magnetograms of active region observed with the Advanced Stokes Polarimeter and low-order adaptive optics system, the magnetic field topology and line-of-sight velocities in two flux cancellation sites were studied. They found that the magnetic field is near horizontal at the place, where two opposite polarities cancel each other. In addition, significant downflows of about 1 km/sec near polarity reversal line, where the field is horizontal, was observed. They interpreted these observations as the direct evidence of the magnetic field submergence at the flux cancellation sites

Future Research Plans

A. Pevtsov plans to study the properties of X-ray and EUV bright points and associated photospheric bipoles, the role of magnetic field in coronal heating, and the relationship between solar drivers and geomagnetic storms. Other research plans include the study of tilt-twist correlation using AR magnetic fields, helicity of rotating sunspots, evolution of delta-spots, and origin of periodic structures in quiescent prominences.

Service

A. Pevtsov supervises the NSO/SP technical librarian, serves as NSO/SP colloquium Chair, reviews NSO/SP observational proposals, and participates in SP/TAC meetings. He also participates in the ATST ASWG meetings and contributed to the science section of the ATST construction proposal. He supervised one NSO summer students and one teacher during summer 2003. Pevtsov also served as co-editor for a special issue of *Advances in Space Research* (Vol. 32 (10)). During FY 2003, he served as a reviewer for two professional journals (*Astrophysical Journal*, and the *Astronomy and Astrophysics* journal) and reviewed scientific proposals for NSF. He conducted several public tours at NSO/Sacramento Peak.

Thomas R. Rimmele, Astronomer

Areas of Interest

Adaptive Optics, Small-Scale Magnetic Fields, Active Region Dynamics, Helioseismology

Recent Research Results

Rimmele and collaborators K. Longhans and W. Schmidt published multi-spectral line observations of g-band bright points. Their program is aimed at understanding the physics of magnetic fluxtubes. Their results support the magneto-convective picture of the formation and dispersal of magnetic fluxtubes. By exploiting the AO systems at the Dunn Solar Telescope for which he is the PI, Rimmele published a paper on plasma flows observed in magnetic flux concentrations and Sunspot fine-structure. He showed that strong and spatially narrow down flows are observed at the edge of magnetic structures such as small flux concentrations, pores and the sunspot umbra. He found strong evidence for what appears to be vigorous, small-scale convection in parts of the umbra and a light bridge like structure in the observed sunspot. A comparison with models shows that the observations clearly favor the cluster model for sunspots. Rimmele, along with the DLSP and AO teams, used adaptive optics and the diffraction limited stokes polarimeter to make diffraction-limited observations of an active region during the strong activity period in Oct-Nov of

2003. The observations included a small sunspot close to the limb on Oct 24th that was part of the region producing the X17.2 flare on October 28th. A movie was produced showing a super-penumbra loop system eruption. It appears that the footpoints of the loops, as well as some loop tops, become bright during the flare. The movie revealed, to our knowledge for the first time, flare structure at scales of 0.2 arcsec.

Future Research Plans

Rimmele leads the NSO solar adaptive optics program and, in collaboration with NJIT/BBSO and the Kiepenheuer Institute, is near the successful completion of a three-year program to build three high-order AO systems for use on the 65-cm telescope at BBSO, the NSO Dunn Solar Telescope, and the 1.5-m German Gregory Telescope. Rimmele will continue his efforts to perform observations at the highest spatial resolution, using frame selection techniques, in order to study the properties and the dynamics of small-scale magnetic elements.

Service

Rimmele is Project Scientist for the Advanced Technology Solar Telescope Project, principal investigator of the NSF/MRI-funded Solar Adaptive Optics Program, and serves as Chair of the Sac Peak site Project Review Committee (PRC). He is also heavily involved in upgrades and implementation of new instrumentation for the DST.

Clifford Toner, Associate Scientist

Areas of Interest

Global and Local Helioseismology, Image Restoration, Data Analysis Techniques

Recent Research Results

C. Toner has devoted most of his time to the support of the GONG++ data reduction/analysis pipeline. He has developed an image-level merging routine which greatly simplifies the analysis of GONG images using local helioseismology methods.

Recent ring-diagram analyses have shown the importance of obtaining accurate orientation estimates for the site images—incorrect values lead to spurious results. Toner is currently using MDI as a fiducial “site” in order to accurately align the entire GONG Network and remove spurious “wobbling” of the merged images. He is also developing a new approach for maintaining the accurate alignment of the Network once MDI is shut down.

Toner leads a small group of people that brought the May 7, 2003 Mercury Transit, as observed by the GONG Network, to the NSO Web page in near real-time. In addition to being a great public relations success, the Mercury transit provided additional information on the absolute orientation of GONG images.

Future Research Plans

C. Toner will continue to devote most of his time to ensuring that the GONG imaged data meet the requirements of local helioseismology. He, and the “Transit Team” will do their best to put the June 8, 2004 transit of Venus on the NSO Web page in near real-time.

Service

C. Toner performs observatory service as Associate Data Scientist for the GONG project. He is also involved in the NSO/NOAO Educational Outreach Program, having given talks and demonstrations at schools and at Boy/Cub Scout functions.

Han Uitenbroek, Associate Astronomer

Areas of Interest

Radiative Transfer Modeling and Atmospheric Structure and Dynamics

Recent Research Results

H. Uitenbroek continues to work on expanding and improving his multi-dimensional numerical radiative transfer code. The most recent additions include the capability to solve for the full four-component Stokes vector in two-dimensional models, and the inclusion of the Zeeman effect in molecular transitions.

Two problems mar the accurate recovery of magnetic field strength from observed line profiles. Limits in spectral resolution limit the accuracy, and the formation height of a given spectral line in the solar atmosphere is not a priori known. Calculations of polarized line formation in a two-dimensional slab from a magneto-hydrodynamic simulation of solar magneto-convection show that using the center-of-gravity method to determine the line-of-sight field strength from observed Stokes V profiles can circumvent the first problem. Uitenbroek has shown that the center-of-gravity method is independent of spectral resolution. The second problem remains, and can only be resolved by extensive forward modeling.

A popular method for tracking small-scale features is narrow-band imaging in the G-band with typical passbands of 1 nm FWHM. This technique is optimal for image improving techniques like adaptive optics and post facto image reconstruction. A drawback of G-band imaging is that it does not provide measurement of the magnetic flux, which has to rely on simultaneous and co-spatial magnetograms obtained in magnetically sensitive atomic lines. It would be preferable if magnetic flux could be measured in precisely those spectral lines that make up the G-band. Recent calculations by Uitenbroek, Miller-Ricci, Asensio Ramos, and Trujillo Bueno with the new transfer code show that this should indeed be possible. Most of the opacity in the G-band is due to electronic transitions in the A-X band of the CH molecule with added contributions from atomic lines of different elements. The CH molecular lines are susceptible to the Zeeman effect in the presence of an external magnetic field and may produce polarized radiation that can be analyzed to infer the properties of the field. When the resulting polarization is calculated in realistic one- and two-dimensional models of the solar atmosphere with realistic field strengths, the detection of magnetic fields through analysis of the Zeeman effect in CH lines indeed seems to be possible.

There is a great need for techniques that can provide measurement of magnetic field strengths in the solar chromosphere. Only a handful of spectral lines are sensitive to the field in these tenuous upper layers. Among them are the Ca II infrared triplet lines the sodium D lines and the hydrogen H-alpha line. The latter has been used for decades to study the morphology of the field in the solar chromosphere, but has not yet been turned into an instrument for accurate field strength measurement. With the Non-LTE Stokes code of Uitenbroek, this is now possible. Socas Navarro and Uitenbroek have investigated the sensitivity of the H-alpha line to the magnetic field in the chromosphere and found that the line can be used to measure fields in the chromosphere of sunspots, but has to be used carefully in quiet non-magnetic regions of the solar surface. This is because the line is equally sensitive to photospheric and chromospheric fields in such an environment.

Future Research Plans

In the coming year, Uitenbroek plans to continue with the development of his radiative transfer code. It will be used to further investigate the nature of G-band bright points, by calculating the G-band spectrum through two- and three-dimensional models of the solar convection. The code will also be used to investigate the viability of the calcium infrared triplet lines for chromospheric magnetic field measurements. Together with Balasubramaniam at NSO, Uitenbroek will attempt to observe the polarization in the G-band due to CH lines that is predicted by the transfer calculations mentioned above.

Service

Uitenbroek is PI of the infrared camera effort at the Dunn Solar Telescope. He also oversees the science exhibit at the Sunspot Visitor Centre and works with K.S Balasubramaniam on the organization of educational outreach programs such as RET/REU and TLRBSE. Uitenbroek served on the Master's thesis committee of Eliza Miller-Ricci at Middlebury College, Vermont. Eliza was a summer student at Sac Peak in 2001. About ten different researchers in different institutes, some even outside the field of solar physics, have requested copies of Uitenbroek's transfer code.

APPENDIX E: DEFERRED MAINTENANCE FY 2004

Facilities Maintenance

NSO must maintain a physical plant at two locations—Kitt Peak and Sacramento Peak. Inasmuch as a special appropriation has never been received to support this maintenance, the facilities must be maintained in good repair through regular allocations of funding. In addition, to regularly schedule maintenance each year, the issues of deferred maintenance are addressed. Deferred maintenance is defined as maintenance that must be regularly scheduled at intervals longer than one year to keep buildings in good working order and to prevent deterioration of the physical plant. Deferred maintenance does *not* include the costs of upgrading facilities—e.g., providing high bandwidth wiring to support computer networks.

The current budgets for the National Solar Observatory remain insufficient to provide for an optimum maintenance program of the facilities at Sac Peak and Kitt Peak. There are, however, sufficient funds to carry out essential maintenance. Year-end funds, to the extent that they become available from vacant positions or indirect charges on grants, are used to supplement this minimum maintenance program. This minimum program will continue until the deployment of the ATST and the disposition of Sac Peak and Kitt Peak facilities. FY 2004 facilities maintenance projects at each site are described below.

Sacramento Peak

During FY 2003 NSO/SP accomplished several moderate to large maintenance projects. They included a major upgrade of the emergency generation facility and the main electric sub-station. These upgrades greatly improve the power transmission and generation facilities at NSO/SP. Also completed this year includes the recoating of the interior of the overhead water tank. This project was funded in FY 2002 and finished in FY 2003. Another project completed during FY 2003 include the upgrade of an apartment to comply with the American's with Disabilities Act, as well as, the rehabilitation of 3 other houses. We also began a major dust remediation project in the Dunn Solar Telescope and began the process of disposing of the Cloudcroft Telescope Facility. These projects will be completed during FY 2004.

The FY 2004 NSO/SP budget includes approximately \$20K for items above the normal reactive maintenance program and approximately \$20K from housing revenues above the normal maintenance for housing. We also expect to have carryover funds of approximately \$25K. The housing revenue funds will be used to upgrade permanent and visitor housing, as well as, contribute to the upgrade and maintain the infrastructure (sewer plant, roads, etc.) Other projects that should be completed within this fiscal year includes upgrading the lighting in the machine shop and exterior painting of the Main Lab. Major projects that will be started, funds permitting, include a required upgrade of our sewer plant, resurfacing of the roads in our housing and the replacement of a staff vehicle.

Table E-1. NSO/Sac Peak Summary of FY 2004 Projects

(Dollars in Thousands)

<i>Project</i>	<i>Est Cost</i>
Sewer Plant upgrade	50
Main Lab Improvements	25
Main Lab/Quonset Painting	10
Housing Upgrades	20
Vehicle Replacement	20
Road Resurfacing	75
Total	\$200

Sewer Plant Upgrade: The sewer plant at Sac Peak has not been upgraded since its original construction 40 years ago. The State of New Mexico Environmental Department has put the Observatory on notice that our permit will not be renewed unless improvements are made that result in better test results for the discharged effluent. This will be a multi-year project that will include consultations with engineers and the State.

Main Lab Renovation: The Main Lab at Sac Peak houses all of the offices for the scientific staff, Director, Library, and other staff. The building requires upgrading in the areas of access for disabled, emergency exit and security. The former photo lab also is available for sub-dividing into additional office space, which is sorely needed. This will be a multi-year project, much of which will be contracted out.

Main Lab/Quonset Painting: The exterior of the Main Lab and several of the storage quonsets require repainting. This will be accomplished using student employees this summer. This is a multi-year project.

Housing Upgrades: We will continue to upgrade housing as funds become available. This will include renovating some visitor housing to make is accessible for the handicapped. This is a multi-year project.

Road Resurfacing: The roads in the housing areas require resurfacing. Deterioration has lessened the impact of maintenance activities and a more lasting remediation must be undertaken. Chip sealing the roads will be explored this year.

Kitt Peak

In contrast to NSO/SP, where NSO is fully responsible for site and building maintenance, KPNO continues to be responsible for the labor and non-payroll associated with the routine maintenance of the solar telescopes of NSO/KP and the Kitt Peak site and facilities. NSO/KP is responsible, at the level of \$30K/year, for non-payroll costs associated with major solar facility maintenance.

Table E-2. NSO/Kitt Peak Summary of FY 2004 Projects	
<i>(Dollars in Thousands)</i>	
<i>Project</i>	<i>Est. Cost</i>
McMath-Pierce Electrical Upgrade	30
McMath-Pierce Painting	15
Re-Roofing and Sealing	5
McMath-Pierce Fall Protection	5
Total	\$ 50

McMath-Pierce Facility: Sections of the wiring and electrical components within the main observing room and the telescope structure as a whole require replacement and upgrade to ensure that the facility remains operational and maintainable.

The aging Telescope Control System (TCS) of the McMath-Pierce constitutes a serious long-term maintenance issue. The current 20-plus-year-old control systems are increasingly difficult to maintain, resulting in downtime. The cost of replacing the TCS with modern, lower-maintenance hardware and software could approach \$300,000 but is not in the summary above since the project cannot be carried out within the current operating budget.

The exterior of the McMath-Pierce was painted in 1991 and has held up reasonably well. Maintenance of the interior surfaces and caulking, however, are long overdue. The section of the interior windscreen just below the top of the pier requires extensive work.

APPENDIX F: NSO MANAGEMENT

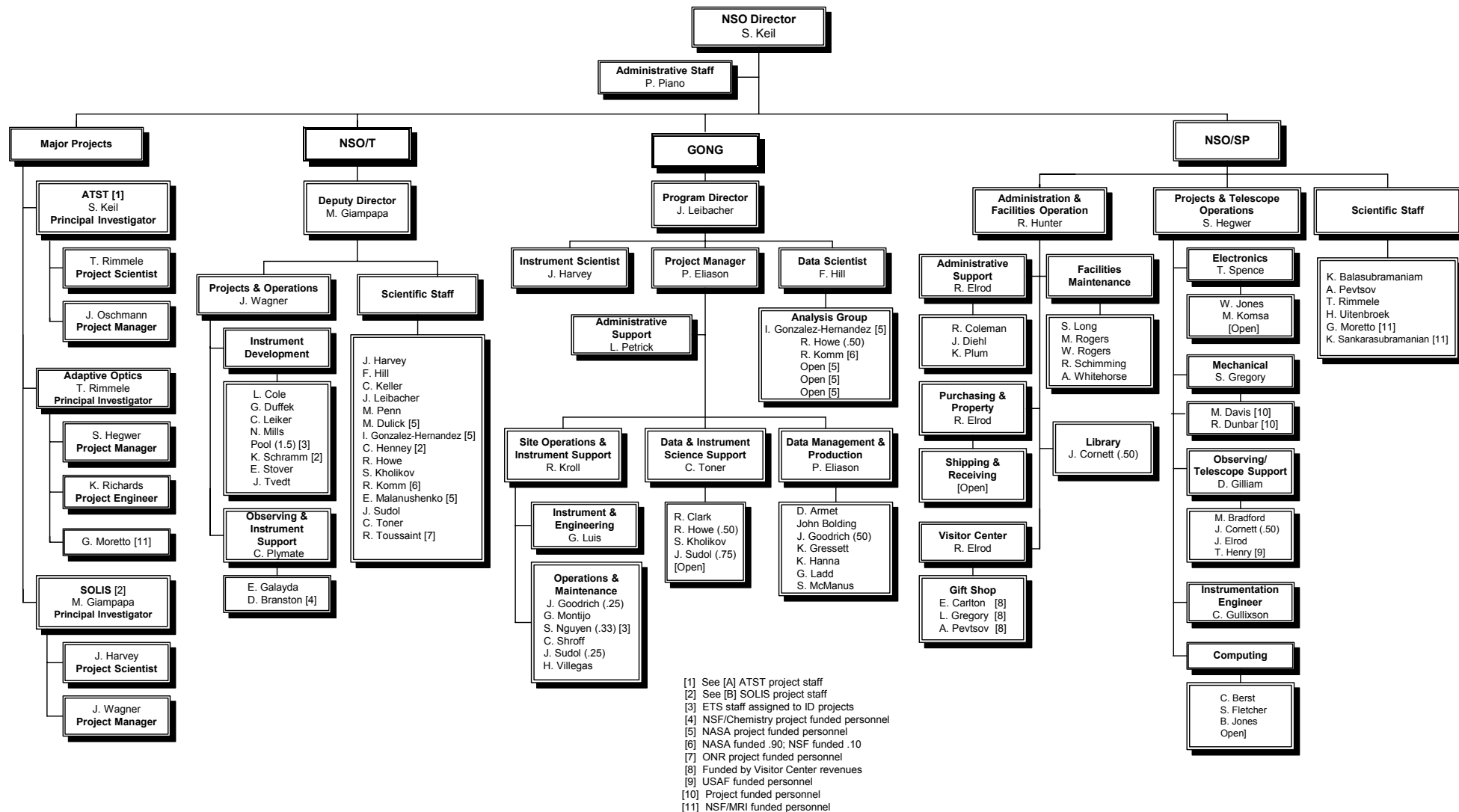
Stephen Keil	NSO Director; ATST Project PI
Mark Giampapa	Deputy Director for Tucson Operations; SOLIS Project PI
Rex Hunter	Site Manager, Sacramento Peak
Thomas Rimmele	ATST Project Scientist; Solar Adaptive Optics Program PI
Jim Oschmann	ATST Project Manager
Stephen Hegwer	Sac Peak Technical Programs Manager
Jeremy Wagner	SOLIS Project Manager; ATST Deputy Project Manager
John Leibacher	GONG Program PI
Pat Eliason	GONG Program Manager

NOAO Managers Who Provide NSO Program Support

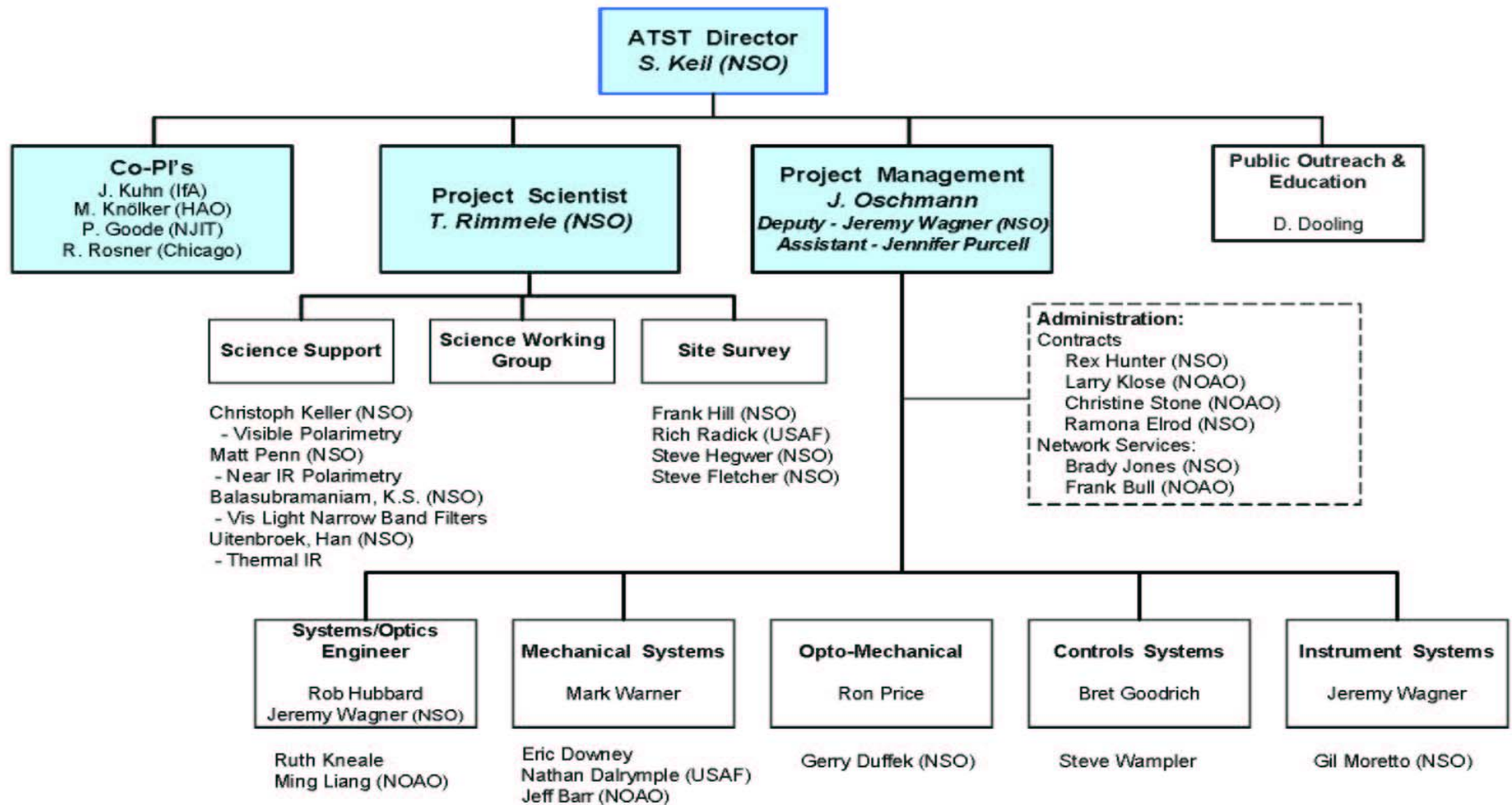
Sandra Abbey	Human Resources Manager
Larry Daggert	Engineering & Technical Services (ETS) Manager
John Dunlop	Central Facilities Operations & Kitt Peak Facilities Manager
Steve Grandi	Computer Infrastructure Services (CIS) Manager
Doug Isbell	Public Affairs & Educational Outreach Manager
Larry Klose	Sr. Contracts & Major Projects Administrator
Patrick Phelan	Business Manager
Chris Richardson	Assistant Controller
James Tracy	Controller
Karen Wilson	Associate Director, Administration & Facilities

APPENDIX G: ORGANIZATIONAL CHARTS

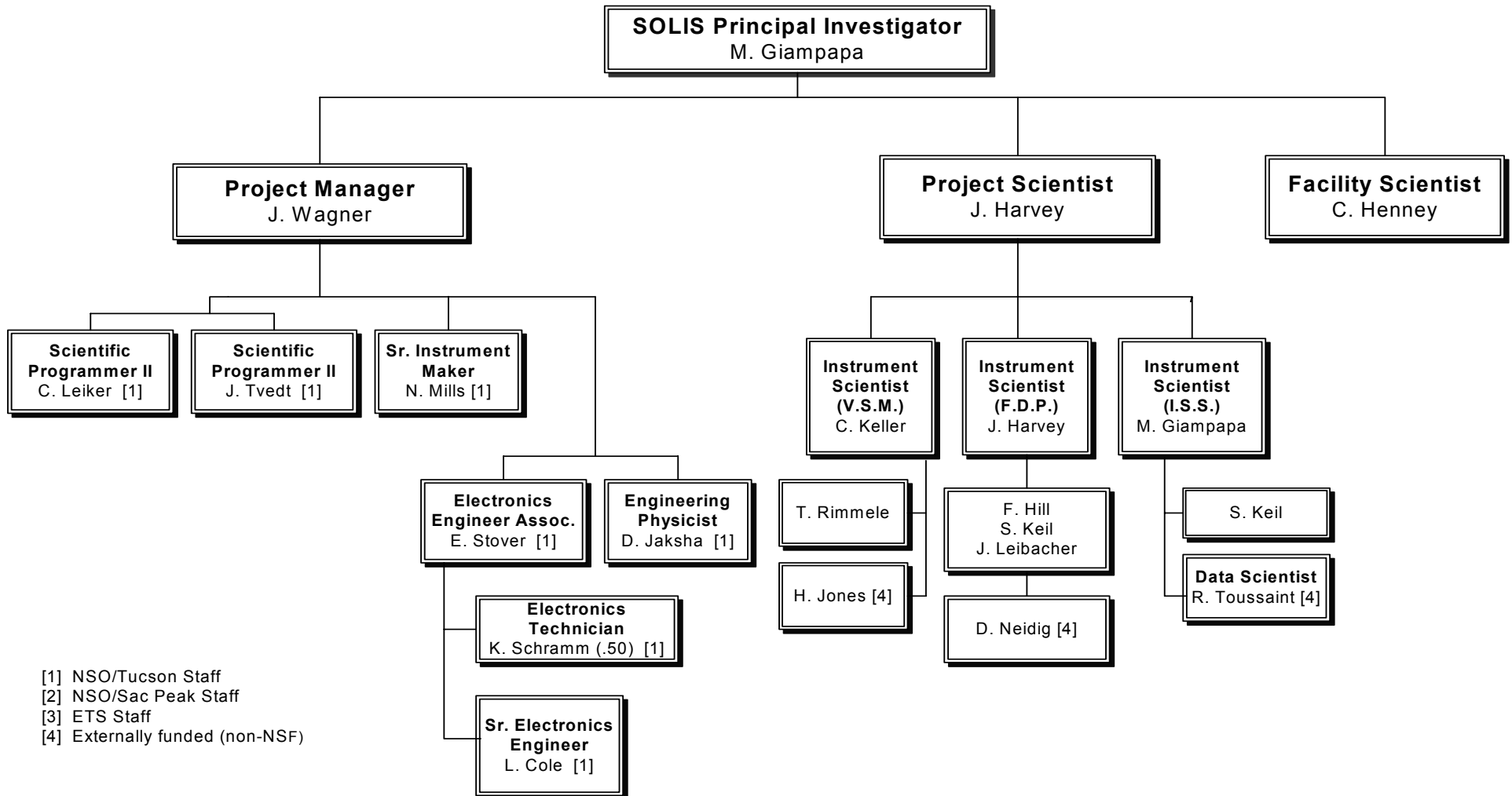
NATIONAL SOLAR OBSERVATORY



ADVANCED TECHNOLOGY SOLAR TELESCOPE ATST PROJECT [A]



SYNOPTIC OPTICAL LONG-TERM INVESTIGATIONS OF THE SUN SOLIS PROJECT [B]



APPENDIX H: ACRONYM GLOSSARY

AASC	Astronomy and Astrophysics Survey Committee
AAS	American Astronomical Society
AFRL	Air Force Research Laboratory
AO	Adaptive Optics
AO76	Adaptive Optics system with 76 degrees of freedom
ARs	Active Regions
ASP	Advanced Stokes Polarimeter
ASWG	ATST Science Working Group
ATST	Advanced Technology Solar Telescope
AURA	Association of Universities for Research in Astronomy, Inc.
BBSO	Big Bear Solar Observatory
CCD	Charged Couple Device
CD-ROM	Compact Disk – Read Only Memory
CoDR	Concept Design Review
CSUN	California State University, Northridge
DASL	Data and Activities for Solar Learning
DHS	Data Handling System
DMAC	Data Management and Analysis Center
DST	Dunn Solar Telescope
EIS	Environmental Information Services
EPO	Educational and Public Outreach
ESF	Evans Solar Facility
ETH-Zürich	<i>Eidgenössische Technische Hochschule- Zürich</i>
EUV	Extreme Ultraviolet
F&A	Facilities & Administration (AURA Fee)
FASR	Frequency Agile Solar Radiotelescope
FDP	Full Disk Patrol
FOV	Field of View
FP	Fabry-Perot
FTS	Fourier Transform Spectrometer
FY	Fiscal Year
GB	Giga Bytes
GONG	Global Oscillation Network Group
GOLF	Global Oscillations at Low Frequencies
GSFC	Goddard Space Flight Center
HAO	High Altitude Observatory
HT	Hilltop Telescope
IAC	<i>Instituto de Astrofísica de Canarias</i>
IBIS	Italian BI-dimensional Spectrometer
IFA	Institute for Astronomy (University of Hawaii)
IR	Infrared
IRAF	Image Reduction and Analysis Facility (NOAO)
ISOON	Improved Solar Observing Optical Network
ISS	Integrated Sunlight Spectrometer
KIS	Kiepenheuer Institute for Solar Physics
KPNO	Kitt Peak National Observatory
KPVT	Kitt Peak Vacuum Telescope

APPENDIX H: ACRONYM GLOSSARY

LTE	Local Thermal Equilibrium
MDI	Michelson Doppler Imager
MHD	Magnetohydrodynamic
MKIR	Mauna Kea Infrared
MRI	Major Research Instrumentation (NSF)
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NJIT	New Jersey Institute of Technology
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NOAO/ETS	National Optical Astronomy Observatory/Engineering and Technical Services
NRC	National Research Council
NSF	National Science Foundation
NSF/AST	National Science Foundation, Division of Astronomical Sciences
NSF/ATM	National Science Foundation, Division of Atmospheric Sciences
NSO	National Solar Observatory
NSO/SP	National Solar Observatory Sacramento Peak
NSO/T	National Solar Observatory Tucson
PAEO	Public Affairs and Educational Outreach
PSF	Point Spread Function
RASL	Research in Active Solar Longitudes
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
SCOPE	Southwest Consortium of Observatories for Public Education
SOHO	Solar and Heliospheric Observatory
SOI/MDI	Solar Oscillations Investigations/Michelson Doppler Imager (SOHO)
SOLIS	Synoptic Optical Long-term Investigations of the Sun
SPD	Solar Physics Division
SPINOR	Spectropolarimeter for Infrared and Optical Regions
SRA	Summer Research Assistant
SRD	Science Requirements Document
SXT	Soft X-ray Telescope (<i>Yohkoh</i>)
TAC	Telescope Allocation Committee
TB	Tera Bytes
TCS	Telescope Control System
TLRBSE	Teacher Leaders in Research-Based Science Education
TRACE	Transition Region and Coronal Explorer
UCSD	University of California, San Diego
UV	Ultraviolet
VMG	Vector Magnetograph
VSM	Vector Spectromagnetograph
VSO	Virtual Solar Observatory
WBS	Work Breakdown Structure
WWW	World Wide Web
<i>Yohkoh</i>	“Sunbeam,” Satellite project of the Japanese Institute of Space and Astronautical Sciences
ZIMPOL	Zürich IMaging POLarimeter