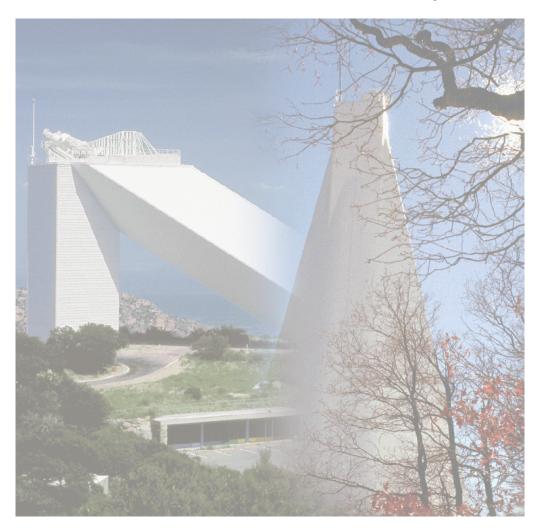


National Solar Observatory



FY 2002 Provisional Program Plan

September 10, 2001





NSO 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.

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INTRODUCTION

The NSO continues its multi-year program to renew national ground-based solar observing assets which will play key roles in a vigorous US solar physics program. Major components of the plan include: developing a 4-m Advanced Technology Solar Telescope (ATST) in collaboration with the High Altitude Observatory (HAO) and the university community; developing adaptive optics systems that can fully correct large-aperture solar telescopes; completing and operating the instruments comprising the Synoptic Optical Long-term Investigations of the Sun (SOLIS); operating the Global Oscillation Network Group (GONG) in its new high-resolution mode; and an orderly transition to a new NSO structure, which can efficiently operate these instruments and push the frontiers of solar physics. The plan recognizes that progress in understanding the Sun requires that it be treated as a global system, in which many critical processes occur on all scales, from the very small (<100 km) to scales that encompass the whole Sun. Development and testing of meaningful physical models require the ability to observe at all these scales. The coupled science goals include:

- Understanding the mechanisms producing the solar magnetic activity cycle Coupling of the surface and interior dynamo processes Creation and destruction of magnetic field
- Coupling of the solar interior and surface Irradiance variations Build-up of solar activity
- Coupling of the solar surface and the envelope Coronal heating Flares Coronal mass ejections (CMEs) Space weather and terrestrial effects
- Exploring the unknown Fundamental plasma – Magnetic field processes

The NSO encourages broad community involvement in its programs through partnerships to build instruments, develop new facilities and to conduct scientific investigations. The NSO successfully led a group of 22 institutions to propose for the design and development of the ATST. The New Jersey Institute of Technology (NJIT)/Big Bear Solar Observatory (BBSO), the Air Force Research Laboratory (AFRL) and the Kiepenheuer Institute (KIS) in Freiburg are collaborating with NSO to develop high-order solar adaptive optics (AO). NSO and HAO have instituted a joint program to develop a high resolution version of the Advanced Stokes Polarimeter (ASP) that will take full advantage of adaptive optics to measure small-scale solar magnetic fields. We have discussed the development of a second and third SOLIS site with both the Instituto de Astrofisica de Canarias (IAC) in Spain which the Spanish would operate in the Canary Islands, and with the Beijing Astronomical Observatory in China. We will continue to work closely with the Air Force, NASA and NOAO to provide critical synoptic observations that, in addition to producing noteworthy science, also support space and other ground-based observations.

This program plan presents in detail what NSO proposes to accomplish in FY 2002 with its base funding of \$7.97M and with the incremental funding it will receive for ATST development. The NSO

plan specifically includes: (1) completion and operation of SOLIS; (2) upgrade of GONG data processing to handle the new large-array camera; (3) development of high-order adaptive optics; (4) completion of the ATST site testing instrument and operation of the site testing campaign; (5) operation of flagship facilities until ATST is on-line; and (6) operation of other facilities as supported by our partners.

The NSO has developed a program that is highly invested in the future need for a healthy US groundbased solar physics program. We have pioneered solar adaptive optics and high-resolution solar physics. With the advent of adaptive optics, the R. B. Dunn Solar Telescope (DST) has been "reborn" into a new role as a diffraction-limited telescope. We have also pioneered the use of infrared (IR) technologies in solar physics. The McMath-Pierce Solar Telescope is the premier facility for IR studies of the Sun, for high-resolution solar and laboratory spectroscopy from the UV to the thermal IR, and for extremely precise polarimetric measurements.

The development of new focal-plane instrumentation and image correction techniques at our existing facilities is leading to new avenues of science (*viz.*, AO and advanced stokes polarimetry at the DST; IR and ZIMPOL (Zürich imaging polarimetry) at the McMath-Pierce, Evans Solar Facility (ESF), and DST; and the SOLIS vector magnetograph (VMG) at the Kitt Peak Vacuum Telescope (KPVT). The development of these scientific paths and new instrumentation will be critical to fully exploiting the even greater potential of the ATST.

NSO solar telescopes provide unique capabilities with unsurpassed focal-plane instrumentation. At both the Kitt Peak and Sacramento Peak facilities, there are dynamical suites of instruments for high-resolution, multi-spectral studies of the solar atmosphere from the photosphere to the corona.

Data from NSO synoptic programs, and GONG in particular, have driven significant progress in understanding solar structure, variability and magnetism. The new SOLIS facility on Kitt Peak will provide high-precision, daily observations of the Sun during its 25-year operational lifetime. NSO programs are widely used and highly leveraged, with operational support coming from the US Air Force, NASA, NOAA, and other groups outside of NSF astronomy.

The sections that follow describe the NSO plan to renew its facilities and instrumentation. Included are descriptions of the 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 program in education and public outreach is described, followed by a discussion of the management structure and investment plan.

NEW SCIENTIFIC CAPABILITIES

The new capabilities being developed at NSO are highlighted in this section. The NSO program is closely aligned with the recommendations of the recent NAS/NRC decadal Astronomy and Astrophysics Survey Committee (AASC) report (Decadal Survey) and with the NAS/NRC report on "Ground-Based Solar Research: An Assessment and Strategy for the Future." Both 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 1 is a roadmap that shows how the NSO facilities will evolve over the next 10 years. During FY 2002 and 2003, NSO plans to replace many of its existing synoptic programs with SOLIS. Operation of GONG, with the enhanced resolution provided by the 1024² cameras, commenced in FY 2001 and will continue in FY 2002. Working closely with the solar community, NSO will continue the concept and development phase for the ATST, including critical technology studies and demonstrations, such as high-order adaptive optics. The goal is to have a design and begin the manufacturing and construction phase in FY 2006. In addition to operating major facilities for the solar community, NSO conducts several community service functions. These include operating the Fourier Transform Spectrometer in support of atmospheric chemistry, planetary physics and other programs, operation of the Radiative Inputs of the Sun to Earth/ Precision Solar Photometric Telescope (RISE/PSPT), development of an on-line digital library for synoptic solar observations, operation of the Liquid Mirror Telescope (LMT) for NASA's space debris program, 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.

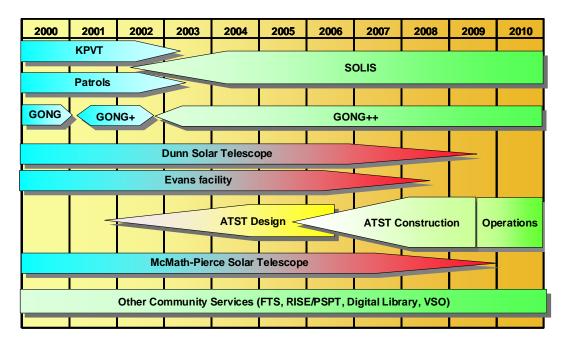


Figure 1. NSO Strategic Roadmap.

Initiatives

Advanced Technology Solar Telescope

The primary goal for the National Solar Observatory is the construction of the Advanced Technology Solar Telescope. When coupled with adaptive optics, the ATST will be capable of breaking the 0.1arcsecond barrier in the visible and providing the resolution needed to analyze the active magnetic microstructure. Models suggest that many of the physical processes controlling atmospheric heating and magnetic field stability occur on scales of $\sim 35 - 100$ km or ~ 0.1 arcsec, and that magnetic fibrils move at velocities of $\sim 0.5 - 0.7$ km s⁻¹ and have lifetimes of ~ 20 minutes. Achieving high temporal and spectral resolution simultaneously with the necessary signal-to-noise (S/N) ratio requires a high photon flux, which in turn requires a large-aperture telescope (≥ 4 m), even for the Sun. It is highly unlikely that a solar telescope of such a large aperture will be deployed in space in the next few decades. In the visible, the ATST will complement forthcoming missions such as SOLAR-B, which will have an aperture of 0.5 m and will operate over a wider field of view than the ATST. Critical diagnostics of the solar magnetic field in the low chromosphere and the corona reside in the thermal infrared, thereby adding a requirement for an all-reflective telescope and low-scattering optics.

Development of a large-aperture solar telescope presents many technical challenges that are very different from those faced by nighttime telescopes. The largest existing solar telescope (on Kitt Peak) has an aperture of 1.5 m and an f-ratio of f/50. Most solar telescopes have used slow f-ratios to minimize thermal problems near the focal plane. The disadvantage is that very large structures are required to house the telescope. To achieve the economy of scale afforded by a faster telescope, the huge flux of solar energy at the focal plane and throughout the telescope must be dealt with. Scattered light is also a critical issue for daytime observations because the Sun is very bright, but features which we wish to resolve are low contrast. Access to even longer wavelengths in the thermal infrared requires an open-air telescope design.

Development of the ATST will occur in stages as shown in the Figure 2. During the latter part of FY 2001, the ATST project began recruiting a design team and establishing a project office. A science working group was formed and the process of establishing a science requirements document is underway. During the latter part of FY 2001, the ATST group also will begin validation of critical technologies needed for design development, to support fiscal planning, and to ensure optimum scientific return from the telescope. These efforts will take advantage of previous work to define large-aperture solar telescopes. Some of the technical issues to be explored include high-order adaptive optics, heat management, scattered light properties, cleanliness management of primary optics, polarization properties, on- or off-axis design, and whether or not the ATST should have coronal capabilities. NSO has started exploring a few of these issues and is committed to a substantial reprogramming of its current and expected resources to support the ATST program.

The choice of a site for the ATST is a critical aspect in its design. The dominant site requirements are: minimal cloud cover, many continuous hours of sunshine, excellent average seeing and many continuous hours of excellent seeing, good infrared transparency, and frequent coronal skies. In order to perform a quality site evaluation and selection for the ATST, an ATST Site Survey Working Group having broad community participation was established. This group will help establish ATST siting criteria, verify the validity of the site testing procedures, and provide advice to the site survey

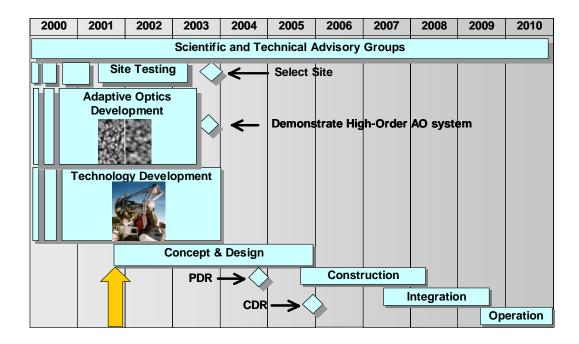


Figure 2. Roadmap for the ATST.

scientist in developing a ranked list of the sites. This list will be presented to the Project Scientist who, after verifying that the science objectives of the ATST can be met, will recommend siting of the ATST to the Project Director. This committee has representatives from other nations that have expressed interest in participating in the ATST. Facilities needed to carry out the measurements (solar dual image motion monitors (S-DIMMs), scintillometers, and sky photometers) are nearing completion and will be fielded in FY 2002. Co-investigators at the University of Hawaii, the High Altitude Observatory, and New Jersey Institute of Technology will be involved with conducting the site testing. Further information on the site survey and site selection can be found in Appendix II, Section 10 of the ATST Design and Development proposal on the ATST Web site (<u>http://www.nso.edu/ATST</u>).

High-Order Adaptive Optics

Adaptive optics corrects for atmospheric distortion of the wavefront in order to achieve diffractionlimited imaging from ground-based telescopes. The next step in fully compensating existing telescopes and for designing the AO system needed for the ATST is the development of a high-order AO system with 80 degrees of freedom. Such a system is adequate to achieve atmospheric compensation at the DST under median seeing conditions and diffraction-limited imaging in the near infrared under good seeing conditions at the McMath-Pierce. NSO has combined resources with the New Jersey Institute of Technology/BBSO and the Kiepenheuer Institute in Freiburg to develop highorder systems that will be installed at the DST, at BBSO and at the proposed GREGOR telescope on Tenerife in the Canary Islands.

A major design goal for the high-order system will be to develop AO technology that is easily scalable to more degrees of freedom, so the technology will be available for the ATST. Operating experience with high-order solar AO from existing telescopes will provide important information about the efficiency achievable with solar AO systems, performance and performance limitations.

This will enable us to design the most cost efficient AO system for future ground-based solar telescopes.

High-resolution observations of the Sun are essential to solving many of the outstanding problems of solar astronomy. The current high-resolution solar telescopes are in the one-meter class. These are limited 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. This problem can be partially overcome by post-image processing, like speckle and phase diversity (e.g., Paxman, R. 1999. Phase-Diversity Data Sets and Processing Strategies. ASP Conf. 183: 311; Keller, C.U. 1999. Optimum Apodization for Speckle Imaging of Extended Sources. ASP Conf. 183: 342). To obtain full benefit from existing telescopes, however, one needs AO with more than 20 degrees of freedom. Going from the current low-order AO system, to a high-order, scalable system represents a major development effort.

In partnership with NJIT and KIS, NSO has started a three-year project to build three high-order AO systems for use on the 65-cm telescope at BBSO, the 76-cm DST of NSO and the planned 1.5-m German Gregory Telescope, GREGOR. These systems will upgrade leading high-resolution solar telescopes—greatly improving the scientific output of each. In the meantime, the adaptation of a low-order AO system at the NSO McMath-Pierce Solar Telescope will yield diffraction-limited imaging in the infrared. These upgraded telescopes will serve a broad solar community with diverse needs, from the individual university researcher to teams conducting campaigns.

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 not trivial. 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 have to be developed in order to be able to fully exploit the scientific capabilities of AO. Having three high-order systems operating at three sites will enable us to investigate implementations of AO under the broadest of situations.

The hardware cost for the proposed project (three systems) is \$1.80M. The development cost is an additional \$2.9M, resulting in a total project cost of \$4.7M. The Kiepenheuer Institute in Freiburg will bear the hardware cost for its system (\$0.55M) and contribute \$0.4M in matching funds to the development cost. NJIT will contribute \$0.8M in matching funds to this project. NSO will contribute \$0.95M in hardware and manpower to the development of high-order AO. In addition, the US Air Force will contribute \$0.1M. An increment of \$1.9M was requested from the NSF Major Research Instrumentation (MRI) program. Thus, in addition to combining forces so that the project has a critical mass, each institution is essentially bearing the cost of the hardware for its AO system. The cooperation will infuse money, facilities, students, and manpower into the project. The same kind of domestic and international cooperation is the way of many future projects.

Design work began in CY 2000, and NSO and NJIT hired two postdoctoral fellows and a student to work at NSO/Sacramento Peak with the project principal investigator.

SOLIS

SOLIS (Synoptic Optical Long-term Investigations of the Sun) is a project to make optical measurements of processes on the Sun whose study requires well-calibrated, sustained observations over a long time period. The major scientific result of SOLIS will be an improved understanding of how and why stars like the Sun produce activity, and how this activity affects human endeavors. SOLIS will be most productive by working in concert with other observational projects, both in space and on the ground. In particular, NASA's High Energy Solar Spectroscopic Imager (HESSI; expected to be launched early in FY 2002), Solar Radiation and Climate Explorer (SORCE; mid-2002), the Japanese-led SOLAR-B mission (Fall 2005), NASA's Solar Terrestrial Relations Observatory (STEREO; November 2006), the planned Solar Dynamics Observatory (SDO; 2007), and others will benefit from SOLIS observations and vice versa. SOLIS will also play an important role in the National Space Weather Program. SOLIS has developed some new techniques and technologies that will prove to be useful to the NSO Advanced Technology Solar Telescope project.

SOLIS consists of three instruments: 1) a vector spectromagnetograph for high-sensitivity full-disk measurements of the Sun's magnetic field; 2) a full-disk imager for high-fidelity spectral images of solar disk activity; and 3) a solar spectrometer for accurate measurements of spectral line profiles of the Sun as a star. The expected 2.3 TB of daily raw data will be processed by state-of-the-art data handling systems and planned improvements to NSO's digital archive will allow reduced results to be promptly available over the Internet. Off-site users will be able to schedule particular observations to support their research and educational programs.

SOLIS will commence operations during FY 2002, after a four-year design and construction period. NSO's superseded synoptic facilities will be retired after a period of simultaneous observations to tie the old and new data together. SOLIS will replace the KPVT capabilities upon completion and deployment to Kitt Peak. In addition, SOLIS observations will replace the program to acquire full-disk spectroheliograms that is conducted at the Evans Solar Facility. Finally, the SOLIS/FDP will replace the white-light and H α patrol programs at the Hilltop Solar Facility. NSO anticipates reaching full and stable initial operational capability of SOLIS during FY 2003. Based on experience with NSO's existing synoptic facilities, NSO expects to make several major improvements to SOLIS during its 25-year operational life.

In its recommendations of small initiatives, the recent NAS/NRC decadal Astronomy and Astrophysics Survey Committee report explicitly recommends building two additional SOLIS vector spectromagnetographs to form a network which would enable nearly continuous observations. Such a network will provide the major data input for the Solar Magnetism Initiative (SMI) proposed by HAO and several universities, with the goal of strengthening solar magnetic modeling and theory. NSO has taken the first steps to comply with this community recommendation by contacting potential foreign partners with attractive sites prior to writing a proposal.

GONG++

The Global Oscillation Network Group (GONG) studies the internal structure and dynamics of the Sun by means of helioseismology — the measurement of acoustic waves that penetrate throughout the solar interior — using a six-station, world-circling network that provides nearly continuous observations of the Sun's "five-minute oscillations". Results to date have substantially advanced our

knowledge of solar internal structure from the core to the surface, and we are now beginning to measure significant structural variations with the solar magnetic activity cycle, as well as on shorter time scales, and localized structures.

GONG will operate over a full solar cycle to refine its measurements of the time-averaged solar structure and to pursue the systematic study of variations in the structure of the solar interior with magnetic activity. The existing 256×256 rectangular-pixel cameras were replaced with 1024×1024 square pixel cameras [an upgrade known as GONG+] in 2001. This upgrade will enable continuous measurement of localized subsurface structures, such as convection cells and active regions, and the use of traditional helioseismic probes closer to the visible surface.

The GONG+ system was designed such that the magnetogram modulator remains in the optical path permanently and thus, as a by-product, makes available full-time surface magnetic flux measurements. The original, once per hour, low spatial resolution magnetograms proved very useful for near-real time solar weather modeling, and we anticipate that the 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.

Global helioseismology to high spherical harmonic degree to probe closer to the solar surface (requiring very large spherical harmonic decompositions and blended mode frequency determinations), and local helioseismology to probe the inhomogeneous and intermittent structure below the surface (tracking and re-mapping for time distance, ring diagrams, acoustical holography) — are very computationally expensive. The large data and flow, complicated analysis, varying user requirements, and voluminous data products dictate a high-performance computing system consisting of a multiprocessor server with a LAN of high-end desktops. The capital cost of this system [known as GONG++] is estimated at approximately \$800K, which will be covered by the allocation of project funds in FY 2001, FY 2002 and FY 2003. The increased operating cost for GONG++ to cover data management, storage media, and processing created by the large increase in data flow is incorporated in the NSO long-range plan and is approximately \$500K more than the current operating cost.

Instrumentation Program

Low-Order Adaptive Optics

The NSO low-order adaptive optics system has become a major tool for investigating the fine structure of solar magnetic fields and their interaction with the dynamic solar atmosphere. The AO system provides a corrected image to several instruments available at the DST, such as the Advanced Stokes Polarimeter, the Universal Birefringent Filter and the dual Fabry Perot system. Results obtained with the AO system can be viewed at <u>www.sunspot.noao.edu/AOWEB</u>.

Recent observational results achieved by using the NSO low-order adaptive optics system at the DST and at the German Vacuum Tower Telescope on Tenerife have yielded provocative new results, showing the presense of fine-scale motions and fields within features, such as magnetic pores and penumbral fibers, that were previously undetected. The deployment of AO is rendering existing solar facilities more productive, allowing users to address fundamental scientific problems, such as the structure and dynamics of magnetic flux tubes, wave propagation along magnetic elements, and generation and dissipation of small-scale magnetic fields.

The next objectives of the low-order adaptive optics program have the following goals and will set the stage for the high-order AO initiative. First, the effort to push the speed of the system beyond the current 25 Hz will be completed. The current system only corrects the image under very good seeing conditions and the faster speed will allow it to correct the images under worse seeing conditions. Post-focus instrumentation will be optimized to use the diffraction-limited imaging provided by the AO system and will be made available to users. Projects to upgrade the Advanced Stokes Polarimeter and narrow-band filters to take advantage of the AO system are now underway.

Advanced Stokes Polarimeter Upgrade

To make precise vector magnetic field observations at the diffraction limit of the Dunn Solar Telescope and for observations covering the entire flux of solar active regions, a new Stokes polarimeter for the DST is currently under construction in collaboration with the High Altitude Observatory. The HAO/NSO ASP has successfully operated at the DST for almost a decade now, but it is limited to 1" spatial resolution and a small field of view. The NSO adaptive optics system in combination with large-format and high quantum efficiency CCD detectors allow us to redesign the ASP for high resolution, which will open new insights into flux tube physics and the formation of active regions.

The ASP upgrade is a joint effort with HAO. The basic concept is adapted from the HAO design for the spectropolarimeter that will fly on the SOLAR-B satellite. The new polarimeter will be built in three phases. The first encompasses the construction of a new spectrograph and scanner; the second includes a new camera system and new modulation, calibration and data acquisition units. The final phase will be permanently installed at the DST and will be fed by a high-order adaptive optics system that is currently under development.

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 microns. NSO has focused its in-house instrumentation program on the 1–5 micron region. The McMath-Pierce also carries out observations in the important 12-micron region through a collaboration with NASA's Goddard Space Flight Center (NASA/GSFC).

NSO's plan for 1–5 micron observations is to take full advantage of NOAO's investment in the ALADDIN array development project. With 16 times as many pixels, higher quantum efficiency, lower read-out noise, and better immunity from electronic interference, a $1K \times 1K$ ALADDIN-based camera will be superior to the current 256×256 camera in every respect and will enable new types of scientific observations, such as vector magnetograms of weak field concentrations and high-cadence studies of chromospheric dynamics. The last year saw several exciting developments in imaging spectroscopy — including the first imaging of water and other molecules in sunspots — that will be prime targets for the new camera.

A high-quality ALADDIN-III array has been identified and assigned by NOAO to NSO. A contract for a camera controller has been signed and a cryogenic enclosure is available. The complete system should be ready for commissioning by the end of FY 2002.

Implementing and demonstrating the scientific value of a fast, large-format infrared camera is an important component of NSO's preparation for an IR-capable Advanced Technology Solar Telescope.

McMath-Pierce Telescope Control System

Upgrades to the telescope control system (TCS) are needed to ensure that the facility remains competitive and maintainable. The upgrades are taking advantage of existing engineering experience within NOAO, as well as experience gained in the SOLIS project. The upgraded TCS will enable accurate pointing, tracking, guiding and scanning of the Main and East Auxiliary telescopes at any coordinate on the solar disk. This capability is particularly needed for collaborative efforts with other ground- and space-based solar telescopes. The recently completed upgrade of the East Auxiliary telescope with a commercial TCS and the development of the SOLIS TCS provide two possible ways to upgrade the McMath-Pierce main TCS.

Seeing Improvement

Tests of potential improvements to the telescope seeing have been conducted in 2000 and 2001. Knifeedge tests, as well as measurements with a Shack-Hartmann wavefront sensor with over 300 subapertures, have provided valuable data and will also aid in designing the ATST. The tests included placement of fans at the location of the 1.52-m primary in order to introduce an air flow over the mirror; this clearly reduced the seeing in front of the mirror. There are plans to install in FY 2002 a series of industrial fans to minimize mirror seeing. This system will essentially consist of a copy of the successful fan system at the European Southern Observatory New Technology Telescope (ESO NTT) in Chile.

Adaptive Optics at the McMath-Pierce

Following development of a successful AO system at the Dunn Solar Telescope, testing of an AO system at the McMath-Pierce telescope has started. A wavefront sensor with over 300 subapertures has been tested, and images between 1 and 5 μ m have been corrected using deconvolution from wavefront sensing techniques. Furthermore, a slow AO system with a 37-actuator mirror has been successfully tested in the laboratory. In FY 2002, the 37-actuator AO system will be moved to the telescope and undergo initial tests in the thermal infrared. In this way, the McMath-Pierce can serve as a test-bed for an AO system at the ATST.

SUPPORT TO PRINCIPAL INVESTIGATORS AND THE SOLAR-TERRESTRIAL PHYSICS COMMUNITY

NSO Telescope Operations

Ongoing upgrades to their focal plane instrumentation have allowed NSO telescopes to remain the most productive and 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 Advanced Technology Solar Telescope. 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.

Flagship Facilities

• Dunn Solar Telescope

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 evacuate 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. The image enhancement program over the past few years has included active control of the temperature of the entrance window to minimize image distortion and high-speed correlation trackers to remove image motion and jitter. Its new, pioneering low-order adaptive optics system provides diffraction-limited images under good seeing conditions. A high-order system that will provide diffraction-limited seeing under moderate to poor conditions is being developed. NSO has pioneered solar adaptive optics and high-resolution, ground-based solar physics as a necessary prelude to the ATST.

Observations with the DST have revealed the fundamental nature of convective overshoot in the solar atmosphere. This led to the realization that solar oscillations are global in nature, and provided the first detection of the locations where the p-modes are excited. Using AO developed by NSO with the DST, in conjunction with the Advanced Stokes Polarimeter developed by HAO, detailed, quantitative measurements of the vector magnetic field associated with sub-arcsecond magnetic flux tubes have been accomplished. Much of our knowledge about sunspots and the evolution of solar active regions has resulted from DST observations. Detailed measurements of sunspot penumbra have revealed the mechanisms leading to the Evershed flow. High-resolution observations of surface flows have revealed twisting motions prior to activity events, which may provide a basis for solar activity prediction. Other highlights include the first measurements of prominence magnetic fields, maps of sub-arcsecond convective motions inside magnetic pores, oscillatory magnetoconvection, measurement of weak fields inside granules and observations of magnetic reconnection in the chromosphere.

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 the 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 has nearly doubled. 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 shown in the Table 1.

• McMath-Pierce Solar Telescope

The McMath-Pierce Solar Telescope 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 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 9.

Infrared polarimetery 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.

Table 1. Telescope and Instrument Combinations FY 2002						
Key: DST = Dunn Solar Tel.	ESF = Evans Solar Facility	HT = Hilltop Tel. KPVT = Kitt	Peak Vacuum Tel.			
INSTRUMENT	TELESCOPE	COMMENTS/DESCRIPTION				
NSO/Sacramento Peak – OP1	TICAL IMAGING & SPECTRO	SCOPY				
Low-Order Adaptive Optics	DST	20-mode correction				
Advanced Stokes Polarimeter (ASP)	DST	Photospheric/chromosphericvector pola arsec/pix	arimetry, visible, 0.375			
Universal Birefringent Filter (UBF)	DST	Tunable narrow-band filter, $R \le 40,000$), 4200 - 7000 Å			
UBF-FabryPerot	DST	Tunable narrow-band filter, $R \le 250,00$	00, 4200 Å - 7000 Å			
Dual-FabryPerot	DST	Tunable narrow-band filter, $R \le 250,00$ 7000 Å, high transmission, current pref 6302 Å				
Horizontal Spectrograph	DST	$R \leq 500,000,~300~nm$ - 2.5 μm				
Echelle Spectrograph	DST	$R \le 2,\!000,\!000,\;300\;nm$ - 2.5 μm				
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograp	h, 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	$H-\alpha$ and white-light full-disk images,	1 min. cadence			
NSO/Sacramento Peak – IR II	MAGING & SPECTROSCOPY					
Horizontal Spectrograph	DST	High-resolution 1 - 2.5 μm spectroscop 300,000	y/polarimetry, R \leq			
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 µm spectrosco	py/polarimetry			
IR Dual Fabry Perot VMG	DST/ESF	Narrow-band imaging and vector magr $\leq 200,000$	etograph, 1 - 2.5 μm, R			
NSO/Kitt Peak – IR IMAGING	& SPECTROSCOPY					
Vertical Spectrograph	McMath-Pierce	0.32 - $12~\mu m,~R \leq 10^6$				
1-m FTS	McMath-Pierce	2200 Å to 18 $\mu m,R \leq$ 600,000				
Near-IR Magnetograph	McMath-Pierce	Vector magnetograph, 1 - 2.5 $\mu m,$ R \approx	180,000			
IR Imager	McMath-Pierce	1 - 5 μm, 256 × 256, 12 Hz, imaging s polarimetry	pectroscopy,			
CCD Cameras	McMath-Pierce	380 - 1083 nm, 576 × 384				
ZIMPOL I	McMath-Pierce	$450 - 1100$ polarimetry, 10 Hz, 300×400	400			

The FTS is thus able to produce high-quality measurements of 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.

Synoptic Facilities

• Evans Solar Facility

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 ESF 40-cm coronagraph is currently used extensively by both NSO staff scientists and visiting astronomers for 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 coronagraph feeds a universal spectrograph, spectroheliograph, Littrow spectrograph, chopping coronal photometer, and a bench where PI instruments can be set-up. Recent instrumentation includes a visible and IR coronal polarimeter, which has 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. The ESF also provides full-disk spectroheliograms in several bandpasses near the Ca II K-line and Ha. There are no plans to upgrade these capabilities as these observations will be replaced by SOLIS. The USAF provides most of the operating support for the ESF.

• Hilltop Solar Facility

The Hilltop facility houses the white-light and H α flare patrols, the coronal one-shot coronagraph, and a multiband solar photometer. In addition, it has a 10-arcsec coelostat that feeds an optical bench currently used by the USAF group at Sunspot in their development of the Improved Solar Observing Optical Network (ISOON) project. 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.

• RISE/PSPT

The Precision Solar Photometric Telescope project comprises a network of three specialized telescopes to provide high photometric precision and high spatial resolution full-disk solar images in the Ca II K line and two other continuum wavelengths. These images can be used to study the irradiance contribution of various solar features, ranging in size from small magnetic field elements to large active regions, and to characterize the global temperature structure. The PSPT instruments are providing valuable data to the Sun-Climate community for understanding the origins of the solar component of climate change. NSO has operated the PSPT for approximately one year until the software system "crashed" in May 2001. HAO operates a data center for the RISE network and NSO currently ships data to HAO and the community from the PSPT site at Sacramento Peak. NSO does not have sufficient

personnel to maintain the PSPT software and hardware. In addition, the software on the HAO system at Mauna Loa has been upgraded for more robust operation. NSO will negotiate a memorandum of understanding for HAO to maintain the software system and provide the Sac Peak system with any hardware changes made to the Mauna Loa system. In exchange, NSO will continue to operate the PSPT and ship the data to the analysis center operated by HAO in Boulder.

• Kitt Peak Vacuum Telescope

The 70-cm Kitt Peak Vacuum Telescope, opened in 1973, is used to make daily maps of solar magnetic and Doppler fields, and intensity maps in several solar spectral lines. These synoptic data sets have proven to be very useful to understanding solar cyclic variations and for supporting space missions and other ground-based observations. The synoptic observing program at the Kitt Peak Vacuum Telescope — a joint effort of NSO, NASA/Goddard Space Flight Center, and NOAA/Space Environment Center (SEC) — has produced a number of research discoveries with subsequent, significant impacts. These include the discovery that magnetic flux concentrations absorb acoustic waves, which initiated the field of high-resolution local helioseismology, or the demonstration that open magnetic fields are associated with coronal holes and high-speed solar wind throughout the solar cycle, which is crucial for forecasting geomagnetic storms. Providing synoptic magnetic and chromospheric data to the solar physics community has resulted in more than 900 papers, theses, and books since 1973. The current SOLIS project will replace the KPVT capabilities when it is completed over the next two years.

Digital Library and Virtual Solar Observatory

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic data sets over the Internet to the research community. Since the inception of the Digital Library in May 1998, a total of 192,019 science data files have been distributed to 10,534 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 made its entire set of daily solar images from the KPVT, FTS spectra, and a growing portion of the Sacramento Peak spectroheliograms available on-line. The holdings of the NSO Digital Library are stored on robotic jukeboxes and are searchable via a Web-based interface to a relational database. This system will grow. SOLIS will generate processed data at a maximum rate of 240 GB per day, with requirements for rapid archiving and user access. A higher capacity storage system will be installed. The next generation of search tools for the Digital Library will contain context-based searches — data will be selectable using quantities computed directly from the data itself, rather than only from information contained in a supplementary header. Digitization of historical photographic solar data sets is in progress and will triple the time span covered by digital solar data.

In order to leverage further the substantial national investment in solar physics, NSO has drafted a plan for a Virtual Solar Observatory (VSO). The VSO would comprise a collaborative distributed solar data archive and analysis system with access through the World Wide Web. 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 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.

SCIENTIFIC STAFF

The responsibilities of a scientific staff member are evenly divided between observatory service and scientific research, but the primary role of the NSO scientific staff is to provide scientific and instrumental innovation. By doing so, the scientific staff provide critical support and leadership to the solar community. 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 NSO 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.

Interior Structure and Dynamics

The development of helioseismology during the last three decades has provided the means to probe the interior of the Sun. Through the GONG project, NSO provides a fundamental data set to study the solar interior over extended periods of time. NSO scientists Rachel Howe, Rudi Komm, and Frank Hill will be utilizing inversion techniques to further their investigation of the distribution of sound-speed changes related to the solar cycle along with the associated frequency shifts. In parallel with this effort, John Liebacher will continue to pursue studies concerning the observational signature of the convective excitation of p-mode oscillations based on GONG data as well as the SOI/MDI instrument on-board the SOHO spacecraft. Meanwhile, NSO Assistant Scientist Cliff Toner will develop new algorithms for the reduction and analysis of local helioseismology data in support of the GONG+ upgrade.

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 is leading to 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 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 ASP 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.

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.

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 plans to extend 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. 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. Using high-resolution imaging at the Dunn Solar Telescope 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 is developing active and adaptive optics for the infrared for utilization at the McMath-Pierce main telescope. Keller has achieved encouraging laboratory results that he intends to extend to actual use at the telescope, ultimately culminating in a user AO system for IR observations at the McMath-Pierce in FY 2003. Furthermore, Keller will continue to use the McMath-Pierce facility to investigate scattering polarization in the photosphere and the

chromosphere, which gives new insight into atoms and molecules and their radiation in the solar atmosphere and properties of weak, turbulent magnetic fields. Observations with the Dunn Solar Telescope using adaptive optics in combination with phase-diverse speckle imaging will be used to study the dynamics of magnetic elements.

Our new scientific staff member, Matt Penn, is developing the NSO-CSUN IR Polarimeter which will be completed in early FY 2002. This collaborative effort between NSO and the California State University at Northridge (CSUN) will yield an instrument that will be used to measure the vertical magnetic structure of solar fields using line pairs; new measurements investigating sunspot umbral oscillations; studies of the multi-scale properties of true solar magnetic fields; vector field measurements of filament magnetic fields; and magnetic splitting in flare emission kernels, among other topics. This effort will also strengthen ties between NSO and undergraduate students at CSUN.

Laboratory Spectroscopy

Mike Dulick, who serves as the NSO McMath-Pierce/FTS Instrument Scientist for visiting investigators funded under the NSF Chemistry 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 participate in projects to upgrade the detectors and data collection system for the FTS.

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 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 both scientifically and technically 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 several graduate (SRA) and undergraduate students (REU) each summer to assist with observations and data analysis. 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. NSO scientists are strongly encouraged and supported to attend national and international meetings to present the results of their research.

EDUCATION AND PUBLIC OUTREACH

NSO has a comprehensive public affairs and educational outreach plan that includes public programs, media information, elements of distance learning (Internet) education, K-12 education, undergraduate and graduate research, teacher research and research-to-classroom experiences. A scientist at each site has responsibility for the local education and public outreach (EPO) program, but they receive support from other members of the scientific and support staff, and during the summer, our resident students. The table below shows the approximate level of support provide to the EPO program. In addition, NSO participates in and receives support from the NOAO's PAEO office (~\$85K). 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 (~\$50K). The total funds devoted to the program including the ~4 FTE's shown in the table, \$80K from NSF for the REU and RET programs, the NOAO support and non-payroll is approximately \$350K or ~4.5% of the total NSO funding. Visitor Center revenues are about \$50K per year, which goes back into its operation and public exhibits. In the near future, this plan will also include combined EPO efforts of NSO and its ATST partner institutions. NSO plans to add two EPO positions, one in FY 2002 second to coordinate our EPO program with the ATST partnership consortium and one in FY 2003 to oversee and expand our current programs and to increase our awareness with the public.

	SRA		WWW						
	REU		Public	WWW	HS/K-12	Pubic	K-12	EPO	
Function	RET	TL-RBSE	Outreach	Sci. Data	Tasks	Tours	Tours	Admin.	TOTAL
Web Master (part-time at each site	e)		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	0.60	0.15	1.00	0.70	0.30	0.60	0.50	0.30	4.15

Table 2. Annual Educational and Public Outreach (FTEs)

Higher Education (Undergraduate, Graduate, and Teacher Research and Education)

Since its formation as a national observatory in 1983, NSO has conducted an annual program that offers undergraduate and graduate students the opportunity to participate in astronomical research programs. Student programs were also conducted annually at both NSO sites prior to 1983. The NSO student program has had a very beneficial impact on solar astronomy in the US and abroad. A large fraction of active solar astronomers have participated in the program.

NSO has participated in the NSF Research Experiences for Undergraduates (REU) program since the inception of the program in 1986. Each summer, approximately eight to twelve students divided equally between the Tucson, Arizona and Sunspot, New Mexico sites — participate in the program at NSO. NSO also supports several graduate students from the US and abroad each year. The graduate students receive excellent training and their presence enhances the experience of the REU students. Close working relationships are encouraged which allow the undergraduates to learn from the experiences of the older students as well as that of the on-site staff. There are currently eight REU students (four in Tucson and four at Sac Peak) and four graduate students (one in Tucson and three at Sac Peak). NSO is participating in the summer 2001 Research Experiences for Teachers (RET) program. Three high school science teachers, two at Sac Peak and one in Tucson, are working with NSO staff scientists. NSO also participated in the Teacher Leaders for Research Based Science Education (TLRBSE) program with NOAO. NSO scientists in both Tucson and Sac Peak provided projects for the teachers and participated in their workshops.

As the national center for ground-based solar astronomy, NSO has the unique advantage of offering broad exposure to the sciences of physics and astronomy. Opportunities to work at either of two locations, coupled with projects ranging from high spatial and temporal resolution studies of the interaction between the solar plasma and magnetic field, to probes of the solar interior using helioseismology, to investigations of the Sun as a star, provide a unique environment for scientific stimulation and growth. Many of the students also participate in instrument development programs, which provide the opportunity to learn how modern astronomical instruments are designed and built.

K–12 Education

NSO actively participates in several programs to enhance science education in grades K–12. The participation occurs through formal programs and informal commitments of staff members to local education. NSO staff are mentors to high school students in local challenge programs in Alamogordo and Cloudcroft, NM school districts and in Tucson, AZ. Staff provide lessons and demonstrations at the Tohono O'Odham Reservation schools. They also produce classroom material through participation in Project ASTRO in both New Mexico and Arizona. NSO staff helped organize and chair Project ASTRO in New Mexico.

Other Public and Educational Outreach

NSO is a strong participant in the Southwest Consortium of Observatories for Public Education (SCOPE). SCOPE is a consortium of research institutions in the southwest that promotes public awareness of astronomy through access and education. The consortium includes NSO, Apache Point Observatory, Kitt Peak National Observatory, McDonald Observatory, National Radio Astronomy Observatory/Very Large Array, and the Whipple Observatory. This valuable collaboration results in excellent interaction among the public and educational outreach staff of these groups and includes cooperative promotion, visitor center display sharing, and the ability to leverage our limited funding into additional outreach opportunities. We produce materials that describe solar astronomy and the effects of the Sun on the Earth for dissemination by SCOPE.

NSO continues to collaborate with NOAO in their public outreach programs on Kitt Peak and in Tucson. Using material from the GONG study of solar oscillations, NSO developed a K–3 solar music educational module. NSO staff members provide public lectures for teacher intern courses, scout troops, amateur astronomers, student clubs, business groups and senior citizens in New Mexico and Arizona. They also participate in the lecture program at White Sands National Monument, and take an active part in educational outreach booths at several fairs including the New Mexico State Fair, Astronomy Day in Albuquerque, NM, and the Robert H. Goddard Days Fair in Roswell, NM.

NSO played a major role in the "Live from the Sun" production by Passport to Knowledge, contributing to two educational video productions, a set of teaching materials, and three WWW chat sessions with students across the US. NSO scientists were interviewed and helped with the

production of segments for national and international documentary and educational films about the Sun. These included participants from the US-PBS, University of Arizona, and public broadcasting stations in Australia, Japan, the United Kingdom and Chile. A CD-ROM of solar images from the NSO Kitt Peak Vacuum Telescope was produced for public distribution. This CD permits viewing of changes on the Sun that occur over the 11-year solar cycle.

NSO Visitor Center

The National Solar Observatory at Sacramento Peak hosts approximately 50,000 visitors annually. NSO visits begin at the Sunspot Astronomy and Visitor Center (Visitor Center). The Visitor Center provides all the necessary visitor conveniences, including vending machines, a gift shop, host/hostess, and interpretive information.

The Visitor Center houses a wide range of interactive displays. These educate the visitor on topics related to the science and research being done at NSO and nearby Apache Point Observatory and to astronomy in general, and to the effect of the Sun on the Earth's environment. In addition to stopping at the Visitor Center, all visitors are encouraged to take guided or self-guided tours of the facilities at NSO. Each year, NSO provides approximately 100 guided tours, about half of which are to school groups. The Visitor Center is virtually self-supporting through revenues from its gift shop and small admissions fee. Currently, revenues from the gift shop are sufficient to pay for all cost of goods sold, for supplies, materials, and personnel required for operation of the Center. As revenues from the Center increase, they will be invested in improved outreach programs such as expanding the number of guided tours and providing more Web-based classroom projects based on solar data.

NSO Public Web Pages

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

NSO Organization

The NSO is a programmatically independent observatory managed by AURA, Inc. under contract to the NSF. NSO, however, continues to obtain services from NOAO. Currently, NSO is divided into two major administrative divisions, NSO/Sacramento Peak (NSO/SP) and NSO/Tucson (NSO/T), and a project division, NSO/GONG. NSO also has project groups for the NSF-funded AO and SOLIS programs, and for ISOON, which is funded by the USAF. A new project office to oversee the ATST is currently being formed and will be fully functional in FY 2002.

NSO currently has 73 permanent employees, including unfilled positions, and 9 project employees working on SOLIS. An additional 30 employees who work at NSO and its facilities are paid by funds from the AF, NASA, NOAA and other partner institutions. In addition, NSO shares support personnel (shops, facilities maintenance, computing, administration) with NOAO in Tucson and on Kitt Peak. A complete set of organizational charts is shown in Appendix H.

The NSO Director's office consists of two employees, the Director and an executive assistant. The Director currently maintains his residence at NSO/SP. A site director for NSO/T also serves as deputy director. The Director spends at least one week a month in Tucson. NSO/SP has a site administrator to manage operations and facilities. In addition, the NSO Director shares support personnel with the 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 staff. Major projects at NSO/SP include development of site survey instruments for the ATST, adaptive optics, and development of the Improved Solar Observing Optical Network for the Air Force. 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. Currently there are 52 personnel at NSO/SP. There are 36 permanent NSF-funded employees, 6 permanent AF scientists, 8 AF-funded NSO employees working on the ISOON project, a postdoc and student funded by NJIT working on high-order adaptive optics, and 2 NSO employees funded by NASA and other sources.

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 and IR camera development. NSO/T also conducts experiments and minor projects to improve Stokes polarimetry techniques, solar-stellar observation techniques, and speckle imaging techniques. NSO/T has 17 permanent NSF-funded staff, 11 NSO employees funded by SOLIS, and 8 funded by NASA and other sources working on data archiving and other projects.

NSO/GONG operates and maintains the GONG network of six telescopes, collects and processes the data, and makes the data available to users. In addition, GONG camera upgrades were implemented in FY 2001. An extended computer capability will be procured and implemented over two years (FY 2001/2002), which will allow processing of the higher resolution data. NSO/GONG currently has 19 NSO employees and 2 employees funded by NASA.

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 consolidation of resources will occur.

FY 2002 Spending Plan

The NSO base budget received from NSF in FY 2001 was \$7.75M, which includes \$1.086M embedded in the NOAO program for services and support and \$154K for the AURA management fee. The NSO program also relies on support from KPNO for operations and maintenance of its telescopes on Kitt Peak. The exact value of this support varies from year to year, depending on the required maintenance levels, and is embedded in the cost of operating Kitt Peak by KPNO.

Table 3 summarizes the funding NSO expects to receive in FY 2002. The NSO program was developed assuming an increase in the base funding level to \$7.97M and anticipated funding for the ATST project of \$1.5M. In addition, NSO is receiving support from the NSF/MRI program, in

Table 3. NSO FY 2002 Funding	
(Dollars in Thousands)	
NSF Base Program Funding	7,969
ATST Project	1,785
AO – MRI Project with $NJIT^1$	400
AFRL Support for Sac Peak Operations	415
NASA Support for Kitt Peak Operations	32
NASA Support for Liquid Mirror Telescope	100
REU/RET Program	80
ISOON Project (USAF)	1,000
Revenue	158
Total Program	\$11,939

1- These funds are sent by NSF to NJIT for the joint NJIT/NSO/KIS/USAF high-order adaptive optics program.

collaboration with NJIT/BBSO and the Kiepenheuer Institute, to support the development of highorder adaptive optics. These funds go to NJIT but cover hardware expenses for both the NSO and NJIT AO systems. The program will receive \$400K in FY 2002. 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 operational support for the KPVT on Kitt Peak. 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.

The NSO budget is allocated to the various tasks NSO must perform to fulfill its mission. Although the budgets for specific programs are determined through a work breakdown structure, the actual allocations occur in functional units (Sac Peak, Tucson, GONG, projects, and the Director's office) as a means of assigning responsibility and budget authority). Table 4 summarizes the planned spending by functional unit and Figure 3 shows the percentage of the programming going to each area.

(Dollars in Thousands)	
	NSF Base
Director's Office ¹	309
AURA Corporate Fee	176
Educational & Public Outreach ²	255
Tucson/Kitt Peak ³	1,726
Sacramento Peak ³	2,193
GONG	3,028
ATST D&D Project	1,785
ATST In-house Contribution	666
Adaptive Optics MRI Program	400
NSO/SOLIS	330
ISOON Project Support	1,000
LMT Operations	100
Total NSO Program	\$11,968

Table 4. NSO FY 2002 Planned Spending by Functional Area

1-Contains \$30K of programmed indirects.

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

3-All scientific staff salaries are contained in the

Tucson, Sac Peak, and GONG allocations.

All of the scientific staff salaries in Table 4 are contained in the Tucson, Sac Peak, and GONG allocations. Thus the table does not show the full effort devoted to the EPO program and the major projects since several scientists will devote a substantial fraction of their time to these programs. The table in Appendix C summarizes the complete NSO budget in more detail.

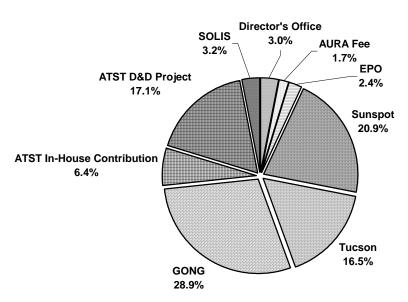
Tables 5-10 break out the spending plan for the major functional units in more detail. The funding summarized on the outreach line of Table 4 that is spent in each functional area is shown at the end of each table. The outreach support received from NOAO for the programs in Tucson and at Sac Peak is shown in the table for the Director's office.

Table 5 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.

(Dollars in Thousands)					
	Payroll	Non-Payroll	Total		
Staff	222	23	245		
Committees	0	10	10		
NOAO Support	40	14	54		
Total Director's Office	\$262	\$47	\$309		
Outreach Support from NOAO	70	16	86		

Table 5. N	SO Director's	Office FY	2002 Base Funding

Table 6 shows the break down for Tucson operations. The \$32K received from NASA supports the operation of the KPVT and will support SOLIS when the KPVT is decommissioned and SOLIS begins operations. Most of the instrument development program will be devoted to putting the ALADDIN array infrared camera on-line.



NSO FY 2002 Budget Summary



Table 7 breaks out the Sacramento Peak operations. 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.

(Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
Scientific Staff	689	43	732	
Software Support	158	10	168	
Instrument Development	111	6	117	
NOAO/ETS → NSO	102	0	102	
Telescope Operations	113	22	135	
NOAO Support	350	122	472	
Total NSO/Tucson	\$1,523	\$203	\$1,726	
Outreach (REU/RET)	30	10	40	

Table 6. NSO/Tucson FY 2002 Base Funding

Table 7. NSO/SP FY 2002 Base Funding (Dollars in Thousands)					
	Payroll	Non-Payroll	Total		
Scientific Staff	423	30	453		
Scientific Support/Computing	190	89	279		
Instrument Development	253	35	288		
Telescope Operations	138	26	164		
Facilities	343	292	635		
Administrative Services	193	20	213		
NOAO Support	141	20	161		
Total NSO/SP	\$1,681	\$512	\$2,193		
Outreach (REU/RET, SRA, Visitor C	Ctr.) 80	49	129		

Table 7 contains the \$415K 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 8 gives a breakdown of how these funds are used to support the AFRL program.

Table 8. Air Force FY 2002 Funding (Dollars in Thousands)					
	Payroll	Non-Payroll	Total		
Scientific Support/Computing	53	29	82		
Telescope Operations	23	5	28		
Instrument Development	90	20	110		
Facilities	66	76	142		
Administrative Services	48	5	53		
Total Air Force	\$280	\$135	\$415		

Table 9 summarizes the GONG spending plan for FY 2002. The new high-resolution GONG cameras will be in operation by the beginning of FY 2002. GONG will complete its acquisition of hardware for the GONG++ full-up operations of the new high-resolution camera systems. 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 participate in the outreach program and receive support from the NOAO outreach line shown in the Director's office budget (Table 5).

Table 9. NSO/GONG FY 2002 Base Funding (Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
Scientific Staff	236	25	261	
DMAC Operations	516	408	924	
Telescope Operations	283	620	903	
Administrative Services	137	10	147	
GONG++ Hardware	0	449	449	
Total GONG	\$1,172	\$1,512	\$2,684	

SOLIS spending will include planned carryover from FY 2001. This reflects both the fact that SOLIS began 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, which requires a modest increase in cost. This will be covered from the NSO base program.

Table 10. NSO/SOLIS FY 2002 Base Funding					
(Dollars in Thousands)					
	Payroll	Non-Payroll	Total		
Construction In-House	130	50	180		
Operations	50	100	150		
Total SOLIS	\$132	\$198	\$330		

ATST Program

Table 11 summarizes both the NSO in-house investment in the ATST and the ATST project funding NSO expects to receive in FY 2002 from NSF/AST. 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 35-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 instrumentation and 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 12. It covers participation in the telescope thermal design, the development of instrument designs for visible and IR polarimeters and in the site survey.

The design and development phase of the ATST project covers five fiscal years, beginning in the last few months of FY 2001 and ending in FY 2005. The actual work to design the telescope will cover approximately four calendar years. Because of the late start in FY 2001, funds will be carried

over to FY 2002 and used do establish the project office and design teams. The teams will consist of an optics group, telescope, site, building and enclosure group, a controls group, as well as the already established adaptive optics group.

The D&D phase will be followed by a three-year construction phase that is planned to begin in FY 2006. A proposal for the construction costs is the main product 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 reuse existing optical, mechanical, and electrical designs that can meet our scientific requirements.

Table 11. NSO/ATST FY 2002 Spending Plan (Dollars in Thousands)					
	Payroll	Non-Payroll	Total		
In-House Contribution					
ATST Tech Trade Studies	50		50		
Adaptive Optics	236	80	316		
IR Camera	50	90	140		
Site Testing	60	100	160		
Total In-House Contribution	\$396	\$270	\$666		
ATST D&D Project Funding					
Project Office/Sys Engineer	212	80	292		
Design Groups	398	319	717		
Collaborator Subcontracts (Design)	230	56	286		
Collaborator Subcontracts (Site Survey)	170	35	205		
HAO Subcontract (ATM Funding)	130	155	285		
Total D&D Project	\$1,140	\$ 645	\$1,785		
Total ATST	\$1,406	\$760	\$2,166		

Table 12. HAO ATST FY 2002 Spending Plan (ATM Funding)

(Dollars in Thousands)			
	Payroll	Non-Payroll	Total
Thermal Analysis	45	15	60
Visible Light Polarimeter	50	60	110
Fiber-Fed IR Polarimeter	30	20	50
Site Testing	30	35	65
Total HAO ATST Program	\$155	\$130	\$285

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. 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 they are replaced by an Advanced Technology Solar Telescope.

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 noncritical maintenance items.
- Restructure base-funded activities at NSO/T not related to SOLIS development and operations to focus on ATST development. Concentrate on IR development and highresolution imaging and spectroscopy in the infrared.
- Both sites would contribute scientific staff time to ATST development (AO, IR technology, and design). Unfilled positions would be used to recruit an ATST project engineers and technical personnel needed to test and evaluate ATST technology.
- Activities at NSO that are supported by other agencies (NASA, AF, NOAA, etc.) will continue as long as they are fully funded.
- 2. Complete SOLIS with current funding carryover plus base support as needed. 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 negotiating with NOAO to continue their support.
- 3. Commit base funding to complete the conversion to GONG++. Base funding may be inadequate to fully exploit the new high-resolution GONG network. Thus GONG will continue to seek NASA support for some of its science operations.

APPENDIX A: MILESTONES FY 2002

NSO Major Initiatives

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 and also will be capable of operating in the thermal infrared. Key activities include developing the science requirements in detail sufficient for conceptual design, evaluating potential sites, and developing adaptive optics and infrared instrumentation. Specific milestones for the ATST and related instrumentation programs include the following:

- Complete the formation of an ATST Project Office.
- Recruit the ATST design teams.
- Implement the critical trade studies.
- Complete the deployment of the site survey telescopes.
- Develop statements of work for collaborating institutions and negotiate contracts.
- Operate the site survey telescopes and begin analysis for site evaluation.
- Begin designing the telescope.
- Prepare for a concept design review (CoDR).

Solar Adaptive Optics

- Complete the high-speed camera.
- Complete the wavefront sensor.

Advanced Stokes Polarimeter Upgrade

• Complete the spectrograph design.

SOLIS

- Complete assembly and testing of the VSM, ISS, FDP and EM instruments.
- Complete testing of the SOLIS mount, VSM and FDP at GONG farm.
- Complete program of cross calibration programs for ISS and VSM.
- Complete the quick-look and first-order data reduction programs.
- Start work on PCA reduction of VSM data.
- Commence use of a DS3 data line from Kitt Peak to Tucson and move SOLIS to Kitt Peak.
- Start initial operations.
- Fix initial startup problems.
- Submit a plan for developing a SOLIS network through partnerships

Telescope Networks for Solar Observations

NSO continues to operate two networks for observations of the Sun: GONG and PSPT telescopes. The primary task for the Global Oscillation Network Group is to certify GONG+ network operations and initiate design of the GONG++ computing system. The Precision Spectrophotometric Telescopes measure changes in the solar irradiance over the surface of the Sun.

GONG

- Certify GONG+ network operations.
- Complete GONG Classic/GONG+ data transitions.
- Procure and implement the GONG++ high-performance computing system.
- Design and commence implementation of the GONG++ pipeline architecture.
- Initiate development of analysis software for high- ℓ global p-mode processing and for local helioseismology applications.

RISE/PSPT

• Establish an MOU with HAO for software/hardware support.

Solar Infrared Program

- Accept delivery of the ALADDIN camera controller from vendor and carry out acceptance tests at the McMath-Pierce Telescope.
- Initiate software development for specialized camera functions such as vector polarimetry and image selection.

APPENDIX B: STATUS OF FY 2001 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2001 Program Plan. (FY 2001 milestones appear in italics below.)

Advanced Technology Solar Telescope (ATST)

Form ATST management structure.

A project scientist was appointed. A program manager is currently being recruited. A site survey working group was formed and a site survey project scientist and program manager were appointed. The project office will form over the next several months.

Develop ATST national and international partnerships.

Several international organizations were contacted and have responded with letters of support and/or commitment to the ATST project. These include the Instituto de Astrofisica de Canarias (IAC) in Spain, Eidgenössische Technische Hochschule (ETH) in Switzerland, the Kiepenheuer Institut für Sonnenphysik (KIS) and the Max Plank Institut für Aeronomie in Germany, the Sterrekundig Instituut in the Netherlands, the University of Oslo in Norway, and a group representing seven universities and observatories in Italy. The IAC and KIS will be active partners in the site survey to test sites on the Canary Islands. KIS is a partner in the high-order adaptive optics program. The next step is to negotiate the level of funding participation these countries will have in the ATST construction phase.

Develop and submit a proposal for the design and development phase.

The ATST design and development phase proposal was submitted to the NSF in December 2000, reviewed in February 2001, and approved by the NSF.

Begin ATST trade studies.

The major trade studies were laid out in the ATST proposal. The necessary studies will be further defined by the ATST Science Working Group in July 2001. The teams to conduct the studies will be formed over the last two months of FY 2001 and the first few months of FY 2002.

Complete and field S-DIMM for site testing.

The S-DIMM telescopes were redesigned, and the first two production units have been completed. The production units were operated jointly with the adaptive optics system for calibration purposes. Further testing of the scintillometer arrays is taking place during the last few months of FY 2001. The towers for mounting the site survey instruments were designed and the first unit will be delivered in August 2001, with subsequent units following every 3-4 weeks. With delivery of the towers, fielding the units to the sites will begin. Negotiations with the known sites for locating the site survey instruments are currently underway.

Solar Adaptive Optics

Improve performance (e.g., bandwidth) of 20 Zernicke AO system.

The performance of the low-order AO system has been characterized by measuring Strehl ratios directly from wavefront sensor data and by applying phase diversity techniques. Strehl ratios up to 0.7 can be achieved during good seeing conditions. New mirror calibration routines were developed and a Twymann-Green interferometer was integrated into the optical setup. The optical setup is highly improved.

Implement 20 Z system at the Dunn Solar Telescope as shared-risk user system. Schedule AO science runs at DST.

Commissioning of the low-order AO system is complete. Adaptive optics is now used routinely in DST observing runs and is operated by the observing staff. During several observing runs, the low-order AO system has produced diffraction-limited imaging and spectral data. Some of these data are currently being analyzed by NJIT graduate students and NSO summer students.

Adapt and/or upgrade post-focus instrumentation for use with AO.

A project to develop a high-resolution version of the Advanced Stokes Polarimeter jointly with HAO was started. A new, compact spectrograph has been design to interface with existing ASP hardware. The mechanical and optical designs are completed. Optical components have been ordered. The mechanical structure is currently manufactured at the NSO/SP shops.

Begin design and construction of high-order AO system.

The high-order project has hired several personnel both at BBSO and at NSO/SP. The top-level system design has been completed. DSP processor boards have been purchased and tested for performance. Based on these tests, a vendor has been selected. The deformable mirrors have been ordered. Conceptual designs for the AO optical benches at NSO/SP and BBSO have been completed, and the tip/tilt correction unit is nearing completion.

RISE/PSPT

Operate RISE/PSPT station at NSO/SP.

NSO successfully ran the PSPT until May 2001. The system crashed and operation was suspended until new software could be installed. HAO has provided an updated software package used on their system on Mauna Loa, but NSO has not been able to divert the resources needed to install and debug the new system. See comments under the next milestone.

Form partnership with HAO and Hawaii for PSPT maintenance and data processing.

A formal partnership has failed to materialize. NSO sends the collected data to the data processing center operated by HAO in Boulder. This data is disseminated to users via the Web and the combined Sac Peak/Mauna Loa PSPT data provides extended coverage of changes in the chromosphere. NSO is now pursuing an MOU with HAO which would provide for HAO maintaining the software and, when they upgrade the hardware for the Mauna Loa system, providing

the same changes for the Sac Peak system. In exchange, NSO will continue operating the PSPT and providing data to the HAO data center.

SOLIS

Complete VSM software control system and complete testing at GONG site.

The VSM was seriously delayed by the inability of a vendor to deliver the required CCD cameras on time. An interim camera system has been contracted, with expected delivery at the end of 2001. VSM testing that requires images is pending arrival of these cameras.

Complete program of cross calibration.

Cross calibration of integrated sunlight observations is underway as weather and instrument conditions permit. The delayed completion of the VSM has led to a strategy in which GONG+ magnetograms may be used as an intermediary calibration between KPVT and VSM observations. The comparison of GONG+ and KPVT magnetograms is well underway.

Move SOLIS to Kitt Peak.

Delayed. This move will not occur until early in 2002.

Start initial operations.

Delayed until 2002.

Fix initial startup problems.

Various problems are diagnosed and cured as they arise during current, ongoing testing. However, the major problems will not be detected until the full SOLIS system is assembled and initial operations attempted.

Submit proposal for SOLIS network.

Delayed until it is demonstrated that the SOLIS VSM produces data of the promised quality.

Complete work on OCS Phase 2.

This work is on track for completion (except for full testing with the actual hardware) by the end of FY 2001.

Complete work on DHS Phase 2.

This work is on track for completion by the end of FY 2001.

GONG

Operate and maintain the network and coordinate activities with the host sites. Reduce network data and deliver it to the community. Continue software development of the GONG+ data acquisition system and data reduction and processing pipeline. Develop analysis software for local helioseismology applications. Pursue funding for GONG++ data processing.

The GONG stations continue to operate reliably, with the scientific duty cycle frequently exceeding 90% and the equipment downtime being less than 2%. Over five months of GONG data from the six-site network have been processed and made available to the community.

The GONG+ cameras were installed in 2001 and the network is operational. The DMAC group continues to process full-resolution images from the GONG+ site instruments, verifying instrument characterization, calibration, geometry, and image merging. We anticipate that data products from the continuous GONG+ data stream will begin to emerge from the pipeline during the first half of FY 2002.

The initial implementation of the GONG++ high-performance computing system — server, on-line disk storage, and tape library — will be purchased at year-end FY 2001. The full-up system will be purchased and installed in FY 2002.

Infrared Array and Controller

Take delivery of controller from commercial firm and carry out acceptance tests for thermal IR camera system at the McMath-Pierce Solar Telescope. Submit joint proposal with HAO and Hawaii for large format IR camera based on HgCd arrays for the Dunn Solar Telescope.

A contract for the design, construction, and delivery of a controller for the $1K \times 1K$ IR camera at the McMath-Pierce telescope has been signed, and work has started. Based on the schedules submitted by the vendor, delivery is expected late in FY 2002.

The potential collaboration with HAO and Hawaii for developing a large-format IR array has not been implemented. Hawaii and NSO are working together to obtain a medium-resolution IR array that will fit into an existing controller.

APPENDIX C: NSO FY 2002 BUDGET & STAFFING SUMMARY

NSO FY 2002 Budget Summary

(Dollars in Thousands)

	Director's						Total
	Office	Sunspot	Tucson	GONG	ATST	SOLIS	Budget
Director's Office	255						255
Scientific Staff		453	732	261			1,446
Scientific Support/Computing		279	168	924			1,371
Instrument Development/Maintenance		288	219	449	506		1,462
Telescope Operations		164	135	903		150	1,352
Facilities		635					635
Administrative Support		214		147			361
Graduate Student Program		20					20
Educational Outreach (REU/RET,K-12 etc)	86	55	40				181
Visitor Center/Public Outreach		55					55
Construction						180	180
Site Testing					160		160
NOAO Operations Support	54	161	472	343			1,030
ISOON Support ¹		1,000					1,000
Liquid Mirror Telescope (LMT) Operations ²		100					100
AURA Management Fee	176						176
ATST Proposal (Astronomy Division Funds)					1,500		1,500
ATST Proposal Atmospheric Division Funds)					285		285
High-Order AO Proposal (MRI) ³		400					400
Total NSO Program	571	3,823	1,766	3,028	2,451	330	11,969
rotal noo riogram	0	0,010	.,	0,010	_,		1,000
Revenues							
NSF MRI		(400)					(400)
NSF ATST Proposal (Astronomy Division)		(100)			(1,500)		(1,500)
NSF ATST Proposal (Atmospheric Division)					(285)		(285)
Programed Indirects	(30)				(===)		(30)
Housing Revenue	((91)					(91)
Meal Revenue		(17)					(17)
NSF/REU Funding		(40)	(40)				(80)
AF Support for Sac Peak Operations		(415)	(10)				(415)
AF Support for ISOON Project		(1,000)					(1,000)
Nasa Support for Kitt Peak Obserations		(1,000)	(32)				(32)
Nasa Support for Liquid Mirror Telescope		(100)	()				(100)
Visitor Center Revenue		(50)					(50)
		1/					(/
Base Program - NSF	541	1,710	1,694	3,028	666	330	7,969
Notes							

1- Anticipated Funding to support AF ISOON Project

2- Anticipated funding from NASA to support LMT Operations

3- Funding goes to NJIT for joint NJIT/NSO/KIS/USAF adaptive optics program

FY 2002 STAFFING SCHEDULE

(In Full Time Equivalents)

	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total
Scientists	1.00	5.00	6.00	3.00			15.00
Engineers/Scientific Programmers		5.50	6.00	6.75		6.25	24.50
Administrative Staff	1.00	7.50	1.00	2.00		0.75	12.25
Technical Staff		9.00	4.00	7.00		4.00	24.00
Maintenance & Service Staff		9.00					9.00
	Total 2.00	36.00	17.00	18.75		11.00	84.75

APPENDIX D: SCIENTIFIC STAFF RESEARCH AND SERVICE

Karatholuvu R. Balasubramaniam, Associate Astronomer

Areas of Interest

Solar Activity Evolution, High Resolution Solar Physics, Advanced Technology Solar Telescope technical issues, Stokes Polarimetry, Solar Mass Ejections, Near-IR Magnetometry, Space Weather

Future Research Plans

K. S. Balasubramaniam (Bala) research interests 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 Solar Polarimeter, tunable narrow-band filters, and micro-lens array spectrograph, for this purpose.

Bala has been working on efforts to understand the magnetic activity of the solar chromosphere from spectroscopy and polarimetric studies. He is working with Han Uitenbroek, Jack Harvey and Harry Jones on understanding the influence of magnetic field on the chromospheric Ca II 854.2 nm spectral line. Using the ASP, he is working on developing methods to understand the magnetic influence on the spectroscopy of H α spectral line.

Using high resolution imaging at the Dunn Telescope as well as Stokes spectropolarimetry from the ASP, Bala is working on understanding the dynamic structure of sunspots in the photosphere and the chromosphere.

Bala and S. L. Keil will continue to analyze data acquired during the previous solar maximum to seek velocity and magnetic field characteristics of active region evolution for solar activity modeling. This includes data obtained with the narrow-band filter and the ASP. Bala is also working on the role of magnetic field in heating process, in solar active regions. He is collaborating with L. A. Smaldone (University of Naples) on understanding upper atmosphere heating using Si I 3905.5 as a thermal diagnostic. He will work on high-resolution quiet-Sun data obtained during the annular solar eclipse of 1994 to calibrate the instrumental response of the DST, and in-turn, use this information as a baseline for active region studies. Working with Allen Gary(NASA/MSFC) and Michael Sigwarth, Bala will continue to exploit observing techniques and the importance of filter imaging with dual-FP and triple-FP cascaded Fabry-Perot Etalons.

Bala will continue to work on the 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.

In collaboration with George Simon (NSO Emeritus), Bala plans to work on understanding solar convection on different spatial scales, using the SOHO-MDI and TRACE data, and their relationship with magnetic structures and their role in solar activity.

<u>Service</u>

Bala is chair of the NSO/SP Telescope Allocation Committee and advises non-NSO users on observing at NSO/SP facilities. He is actively involved in the summer NSF 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 the planning and execution of the Advanced Technology Solar Telescope. He is a member of the site-survey working group as well as the science working group for the ATST.

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.

<u>Service</u>

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 and his colleagues, R. Radick (AFRL), J. Hall (Lowell Observatory), and S. Baliunas (SAO), have completed a survey of chromospheric Ca II H and K line emission 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. The survey results will be submitted for publication in FY 2002. In addition, M. Giampapa and his collaborators have implemented a long-term program with WIYN/Hydra to begin an investigation of long-term variability analogous to what would be expected from cycle-like modulations of chromospheric activity. These data are now being reduced and analyzed.

Finally, Giampapa, in collaboration with D. Soderblom (STScI), have received time on the 9-m Hobby-Eberly telescope with the High Resolution Spectrograph to obtain projected rotation measures of the solar-type stars in M67. The objective of this project is to verify whether activity levels that are higher than those values that characterize the maximum in the solar cycle in some Sun-like stars in M67 are possibly due to rotation rates that are greater than the solar value.

Future Research Plans

Giampapa intends to continue working on the M67 project.

In collaboration with T. Fleming (Steward Observatory, U. of Arizona), Giampapa is analyzing Chandra data on low-mass stars. Thus far, their work has produced a detection of quiescent coronal Xray emission in the lowest mass star yet seen in the X-ray, VB 10. Giampapa and Fleming plan to submit proposals to the XMM Guest Investigator program to extend their work on X-ray observations of brown dwarfs and low mass stars near the critical mass limit for hydrogen core burning. In collaboration with Dr. Eric Craine (Western Research & GNAT, Inc.), Giampapa continues to investigate the application of small, robotic telescopes equipped with CCDs for high-precision photometry of solar-type stars in clusters such as M67. The scientific objective is to measure lowlevel, luminosity changes in sun-like stars analogous to the activity-related variations seen in the Sun.

<u>Service</u>

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 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 2001, J. Harvey concentrated on SOLIS and the upgrade of GONG, leaving little time for scientific research. However, he was able to use some of the early GONG+ data to unambiguously detect magnetic field changes associated with large solar flares. He also worked with K. S. Balasubramaniam, H. Jones and H. Uitenbroeck in a careful study of Zeeman splitting of the Ca II 854.2 nm spectrum line. He worked with C. Henney to confirm the existence of a coherent 27.03 day period in the activity of the Sun since 1975. Using proxy measurements for earlier times, the coherency of the signal breaks down. A number of research projects are suspended pending the completion of SOLIS.

Future Research Plans

During FY 2002, J. Harvey will continue to concentrate on the SOLIS project and, consequently, it is again unlikely that any significant research will be accomplished.

<u>Service</u>

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.

Carl J. Henney, Assistant Scientist

Areas of Interest

Solar MHD, Polarimetry, Solar Activity Cycles, Solar Evolution, Helioseismology, Asteroseismology

Recent Research Results

Henney is comparing KPVT integrated full-disk synoptic signals with recently published solar wind velocity results that showed evidence for active solar longitudes. As a byproduct of this work, he is developing a method to use signal phase information to measure the coherency of long-lived signals. This new analysis method may potentially be helpful for helioseismic analysis of very low frequency

mode candidates. In addition, Henney has continued collaborative work with L. Bertello, F. Varadi and R. Ulrich of UCLA in the analysis of the GOLF and MDI velocity signals in the search for low frequency solar oscillations.

<u>Service</u>

As Data Scientist for the SOLIS project, Henney oversaw the development and testing of the data handling system during the past year. He created C-based data reduction procedures critical in the production of SOLIS-VSM 630 and 854 nm longitudinal data products in near real-time. Integrated with the SOLIS DHS, these procedures saw "first light" using VSM-simulated data. Henney also generated and successfully tested a preliminary procedure to flat field calibrate the SOLIS-ISS. He also co-maintained the current Kitt Peak Vacuum Telescope synoptic data pipeline and modified the KPVT synoptic data reduction pipeline to process SOLIS-VSM synoptic data as part of the SOLIS DHS. In addition, he is developing new solar activity forecast maps, using KPVT synoptic data, which will be publicly available on the WWW during year 2001. Additionally, in collaboration with F. Hill and H. Jones, Henney originated the solar "active longitude" educational research project with the Teacher Research Based Science Education program.

Frank Hill, Scientist

Areas of Interest

Helioseismology, Asteroseismology, Fluid Dynamics of the Solar Convection Zone, the Solar Activity Cycle, Digital Libraries

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 dynamics of the solar interior. Using GONG and MDI data, Hill and co-workers found that the rotation rate of the tachocline, the transition region between the convection zone and radiative interior where the solar rotation changes from differential to solid-body, is periodically accelerating and deccelerating with a time scale of 1.3 years. They have also found that the torsional oscillation velocity pattern seen at the surface penetrates 60,000 km below the surface. These new observations provide clues to the basic mechanism of solar activity. In addition, Hill and co-workers measured the acoustic spectral line widths and amplitudes from GONG spectra. They found that the widths increase and the amplitudes decrease with solar activity, suggesting that less energy is contained in the p modes at solar maximum. This missing energy may be reappear as part of the observed increased irradiance at solar maximum. With groups at the U. of Colorado, Stanford, and the IAC, Hill has applied ring diagram analysis to helioseismic data to create spatially-resolved maps of the depth-dependent flows in the convection zone. Time series of these maps show that active regions block the flows, and that a counter-cell of meridional flow may be forming near the north solar pole.

<u>Service</u>

Hill serves as the GONG Data Scientist, developing algorithms for the reduction and analysis of data for global helioseismology. Hill serves as the NSO Digital Library Scientist, using an NSF Space Weather Program grant to place NSO data on-line and accessible over the Internet. This service is now available at the URL http://www.nso.noao.edu/diglib. Hill is working on Stokes inversion algorithms and data archiving plans for SOLIS. He has been placed in charge of the ATST site survey, and has written a white paper for a possible Virtual Solar Observatory. Hill typically supervises several staff, currently three scientists.Hill is a member of the NOAO Stellar Oscillation Network Group (SONG) Steering Committee, the IAU Commission 12 Organizing Committee, the IRIS helioseismology network Scientific Committee, and the NASA Space Physics Data System Solar

Physics Discipline Team. Hill is a member of the NSO Telescope Allocation Committee. He continues as a participant in Project ASTRO.

Rachel Howe, Junior Scientist

Areas of Interest

Helioseismology, The Solar Activity Cycle, Peak Fitting

Recent Research Results

With R. Komm and F. Hill, Howe has been studying the variation of mode frequencies and splitting coefficients from GONG data in the new solar cycle. The work has now been extended (with S. Basu and H. M. Antia), using inversion techniques to investigate the distribution of sound-speed changes related to the solar cycle, and a paper on this subject was recently accepted by MNRAS. Further work on solar-cycle frequency shifts is now in progress.

In collaboration with J. Christensen-Dalsgaard (Aarhus, Denmark), M.J. Thompson (Queen Mary and Westfield College, UK), J. Schou (Stanford) and others, Howe continues to study the rotational structure of the Sun based on MDI and GONG data. Recently this group, together with R. Komm and F. Hill, has been carrying out a major exercise in comparing GONG and MDI results from selected 3-month periods in an attempt to clarify the systematics involved in the analysis methods. This work was presented at the GONG '99 workshop, the SOHO10/GONG2000 workshop and the 2001 SPD meeting. and is currently being prepared for publication.

Howe continues to work on improved techniques for estimating mode parameters from GONG data in regimes where the standard GONG PEAKFIND algorithm is unsuitable.

Future Research Plans

Howe intends to continue working on the above areas.

<u>Service</u>

In addition to the research activities described above, Howe shares with R. Komm the (informal) responsibility for checking the results of the GONG PEAKFIND analysis.

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

S. Kasiviwanathan (Sankar) has developed a polarimeter for the Kodaikanal Tower Telescope at Kodaikanal, India. The instrumental polarization introduced by the oblique reflection of the telescope was studied and modeled from the observed profiles. In order to verify the model parameters, an ellipsometer was developed. Codes were also developed to invert the peculiar Stokes profiles. A complete code was developed to use the Polarimetric data from Kodaikanal in order to map the vector magnetic fields of sunspots. Line-of-sight velocities around neutral lines were identified. A recent analysis of the ASP-data taken with AO, showed interesting properties of V-profile asymmetries. A bisector analysis of the V-profiles shows a linear correlation with the asymmetries. The downflows around small-scale fields are identified using the bisector analysis.

Future Research Plans

With the low-order AO system developed at the Dunn Solar Telescope, observations will be

carried out in combination with ASP. Simultaneous observations for the magnetic field and velocities will be done in order to look for any correlation between the two. The velocities near neutral line can also be studied. Velocities at these regions can be compared for the non-flaring and flaring sunspot to look for any potential prediction of flares. Inversion of very small polarization profiles (<1%) using wavelet de-noising techniques. Simultaneous measurements of velocity using g = 0 line and the vector field measurements will be used to identify the flow patterns around the magnetic field regions.

Stephen L. Keil, Director, NSO

Areas of Interest

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

Recent Research Results

Working with REU students Erica Raffauf (University of Indiana) and Michael Eydenburg (New Mexico Institute of Mining and Technology), Keil has continued his investigation of the correlation between disk-integrated flux measurements in the core of the Ca II K-line and total plage area and plage brightness obtained from K-line spectroheliograms recorded nearly simultaneously with the disk-integrated observations. The goals are to calibrate the contribution of various atmospheric features to the disk-integrated flux and to relate rotational modulations of the disk-integrated flux to the rotation of the contributing features. The latter results can be used to interpret similar measurements on stars. Results of the work were present at the AGU-AAS/SPD meeting in May 2001 in Boston.

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. He is also part of a team developing all-sky cameras for measuring solar mass ejections as they propagate through the interplanetary medium. These cameras will be flown on the DoD CORIOLIS mission in 2003.

<u>Service</u>

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, Asteroseismology, High-Precision Imaging Polarimetry, Image Reconstruction Techniques, Telescope and Instrument Design

Recent Research Results

In collaboration with Rick Paxman, John Seldin, Dave Carrara, Kurt Gleichman from ERIM International and Thomas Rimmele, I obtained the most highly resolved magnetogram movies. The combination of Phase-Diverse Speckle Imaging, the adaptive optics system at the Dunn Solar Telescope, the Zürich Imaging Polarimeter I (ZIMPOL), and speckle deconvolution delivered stunning sequences of the evolution of small-scale magnetic features in the solar photosphere with a consistent spatial resolution of better than 0.2 arcsec.

Future Research Plans

Apart from working on SOLIS, which will use the major fraction of Keller's time during the next year, he will work on the design and development of the Advanced Technology Solar Telescope. He will continue to use the McMath-Pierce facility to investigate scattering polarization in the photosphere and the chromosphere, which gives new insight into atoms and molecules and their radiation in the solar atmosphere and properties of weak, turbulent magnetic fields. Observations with the Dunn Solar Telescope using adaptive optics in combination with phase-diverse speckle imaging will be used to study the dynamics of magnetic elements. Finally, active and adaptive optics for the infrared will start to be developed for the McMath-Pierce main telescope.

<u>Service</u>

Keller is the telescope scientist for the McMath-Pierce telescope. He provides observing support at the McMath-Pierce and sometimes at the Sacramento Peak facilities. He is the lead scientist for the realtime software and hardware efforts for SOLIS and leads the Vector-Spectromagnetograph effort. Furthermore, he is heavily engaged in the various ATST activities. Keller is a member of the local and NSO-wide Project Review Committees and reviews observing proposals for other national and international facilities.

Rudolf W. Komm, Junior 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. With four years of GONG data available, it is possible to study the solar cycle variation of acoustic mode parameters in unprecedented detail. 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. Komm is working on improving the estimates of the mode parameters of the solar acoustic oscillations which are the fundamental data for helioseismology. Improved estimates are required to make substantial progress in the understanding of the solar interior. Komm is working on advanced time-series analysis such as empirical mode decomposition and wavelet transform to evaluate their usefulness for helioseismology.

Future Research Plans

Komm 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 in order to evaluate their usefulness for helioseismology. With these techniques, Komm will study the relation between p-mode energy and magnetic activity as a function of latitude and time (in collaboration with M. Roth, Freiburg, Germany). Komm will continue to study temporal variations of surface magnetic activity and large-scale flows (in collaboration with J. Javaraiah, Bangalore, India).

<u>Service</u>

Komm continues as a participant in Project ATSTRO.

John W. Leibacher, Astronomer

<u>Areas of Interest</u> 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.

<u>Service</u>

Leibacher serves as the Director of the Global Oscillation Network Group program. He serves on the editorial board 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

Matt Penn has been involved in recent measurements of Zeeman splitting in near-IR coronal emission lines and has measured inverse Evershed flow speeds using He I 1083 nm. He is also involved with spectropolarimetric measurements of emission lines from solar system sources.

Future Research Plans

Penn will be closely involved with the new NSO IR camera project using a 1024×1024 ALLADIN array, and will address several scientific questions with spectroscopy from 1 to 4 microns.

He will continue to work with S. Walton, G. Chapman and A. Cadavid at California State University, Northridge to develop the San Fernando Observatory Infrared Camera, and use the camera for a variety of spectropolarimetric projects related to space weather.

Future Service

Penn will be closely involved with the ATST project, particularly concerning the IR and corona aspects of the telescope. He will also work with SOLIS data, and he is interested in expanding the impact of the NSO at universities.

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, Penumbral Fine Structure, Vector Polarimetry; Space Weather: Solar Drivers

Recent Research Results

A. Pevtsov worked with researchers from other institutions on several studies including cyclic variation of number of X-ray bright points and photospheric bipoles, hemispheric helicity rule for solar

cycle 22 and 23, helicity of large-scale magnetic field, a correlation between X-ray luminosity and magnetic flux, and properties of magnetic clouds resulting from eruption of sigmoids.

Properties of X-ray bright points (XBP) and photospheric bipoles have been studied using soft X-ray data from Yohkoh satellite and NSO/Kitt Peak daily magnetograms from April 1991–December 2000. It has been found that XBP numbers follow well-known anti-cycle variation, but the number of photospheric bipoles is independent of solar (sunspot) cycle. This inconsistency between XBP and bipole numbers implies that the X-ray bright points cyclic variation is not real, but rather a "visibility" effect.

The hemispheric helicity rule has been studied using Haleakala Stokes Polarimeter vector magnetograms, soft X-ray Yohkoh images, and large-scale magnetic field reconstructed using SOHO/MDI full-disk magnetograms. It has been shown that the hemispheric helicity rule is independent of solar cycle in all three data sets. In a separate study, it has been discovered that the current helicity of large-scale magnetic field exhibits latitudinal pattern, which is similar in appearance to the torsional wave pattern observed with GONG and MDI instruments.

A short investigation of X-ray luminosity and unsigned magnetic flux for several different objects (quiet Sun, X-ray bright points, solar active regions, Sun as whole, K, G, and M dwarfs and T-tauri stars) has revealed a close-to-linear correlation between magnetic and X-ray fluxes over 12 orders of magnitude. This result was included in recent review of the Yohkoh mission prepared for NASA's Senior Review 2001 of Sun-Earth Connection Mission Operations and Data Analysis (MO&DA) Programs.

Properties of over 40 eruptions have been studied using Yohkoh SXT images and in-situ interplanetary measurements. It has been found that magnetic clouds resulting from erupting sigmoids form a distinctive class of events, whose leading polarity is determined by active-region magnetic field, not by the large-scale solar dipole orientation. It has been suggested that active region sigmoids and disappearing filaments are the origins of two different classes of CMEs.

Future Research Plans

A. Pevtsov will continue to study the properties of X-ray 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 non-Hale polarity active regions, tilt-twist correlation using ARs magnetic fields, and the evolution of delta-spots.

<u>Service</u>

Pevtsov has supervised NSO/SP Technical Library, served as temporal NSO/SP colloquium Chair, reviewed NSO/SP observational proposals and participated in the SP/TAC meetings. He supervised one NSO summer student and one teacher-participant of the NSO's RET program. He wrote two one-page brochures on solar rotation and nuclear reactions for the Sunspot Visitor Center. Together with H. Uitenbroek, he worked on organizing the next NSO/SP Summer Workshop (postponed till March 2002). During FY 2001, he served as a reviewer for two professional journals, i.e. Solar Physics and the Astrophysical Journal, and on a NASA review panel.

Thomas R. Rimmele, Associate Astronomer

Areas of Interest

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

Recent Research Results

Rimmele has published results from high-resolution observations of umbral fine structure. He found evidence for oscillatory magnetoconvection in a sunspot light bridge. Oscillatory convection in strong

magnetic fields has been predicted by theoretical models but never observed before. Rimmele collaborates with P. Goode and L. Strous (NJIT), and Tuck Stebbins (JILA), studying the excitation of solar oscillations. Their observations show that acoustic power is generated in intergranular lanes and give a detailed description of the mechanism responsible for the conversion of convective energy into acoustic energy. They are also able to show that the acoustic energy is fed into the resonance modes of the Sun.

Future Research Plans

Rimmele leads the NSO solar adaptive optics program and, in collaboration with NJIT/BBSO and the Kiepenheuer Institute, has begun 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 planned 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.

<u>Service</u>

In an ongoing effort, Rimmele is working with R. Radick (NSO/SP/AFRL) and R. Dunn (NSO/SP) on improving optical performance of the Dunn Solar Telescope (DST). Rimmele is developing narrowband filter capabilities for the DST using Fabry-Perots and participates in an ongoing effort to upgrade CCD detectors at NSO/SP. 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).

<u>Clifford Toner, Assistant Scientist</u>

Areas of Interest

Global and Local Helioseismology, Image Restoration, Data Analysis Techniques

Recent Research Results

Toner has devoted most of his time to the support of the GONG+ upgrade. He ran comparisons been GONG+ and MDI data, showing that there is a high degree of correlation (correlation coefficient > 0.85) up to spherical harmonic degree l of ~600. Above this value terrestrial seeing progressively degrades the GONG+ data. However, there is significant signal up to l-values of ~1000. This is sufficiently high for local helioseismology. When the first GONG+ instrument was deployed at Big Bear, Toner used simultaneous data obtained by the GONG+ proto-type instrument in Tucson to confirm that the high-resolution data can be successfully merged, and that it will provide higher quality spectra than merged GONG Classic data. Toner has developed an algorithm which will allow the merging of GONG+ data with GONG Classic data, so that it will be possible to maintain a high duty cycle during the period of time when the "Classic" network is being replaced with "Plus" network. Toner has also improved the determination of the relative angular orientation of GONG+ images to ~0.002 degrees and has developed a method for measuring periodic errors which are introduced by the gears which drive the camera rotator mechanism at each GONG instrument.

Toner has been collaborating with visiting scientists to investigate differences between velocity and intensity using local helioseismology techniques (ring-diagrams).

Future Research Plans

Toner will continue to devote most of his time to the support of the GONG+ upgrade.

<u>Service</u>

Toner performs observatory service as Assistant 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 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 telescope at Kitt Peak, reveal the important role solar granulation plays in the formation of these CO lines. Under excellent seeing conditions, the cores of strong CO lines display a brightness pattern of inverted granular contrast with bright inter-granular lanes surrounding dark granules. The small dark features corresponding to granule centers represent the darkest (and thus coldest) features observed in CO at disk center and may be responsible for the controversial dark CO line cores observed at the solar limb. The inverted granular contrast can be explained with three-dimensional radiative transfer calculations of CO line formation. Uitenbroek has performed such calculations through a snapshot of a theoretical hydrodynamic granulation simulation, showing that the inverted contrast is due to convection overshoot into the stable overlying layer, which causes expansion cooling over granules and compression heating over inter-granular lanes. Uitenbroek also performed non-LTE CO line formation calculations in a series of one-dimensional snapshots from a chromospheric radiation-hydrodynamics simulation. These calculations confirmed earlier results stating the CO lines form in LTE (and thus give reliable information of temperatures), but also drew attention to the fact that CO concentrations may not be in chemical equilibrium. Explicit calculations of CO formation and dissociation rates are needed.

Uitenbroek has been improving and expanding his multi-dimensional numerical radiative transfer code. The performance of the numerical code under partial frequency redistribution (PRD), which is needed to model and analyze strongly scattering lines in the solar spectrum, is now on par with that under complete frequency redistribution (CRD), which is more commonly used. The code is publicly available and several people in the community have requested a copy. The most recent addition to the code is the capability to perform angle-dependent PRD calculations. This is needed instead of the computationally simpler angle-dependent approximation when inhomogenities and/or macroscopic velocity fields increase the anisotropy of the radiation field. With this new version of the code, Uitenbroek has investigated the influence of PRD on the radiative cooling in the CaII H and K lines. These play an important role in the energy balance of the solar chromosphere. The detailed structure in the recent dynamical models of the solar chromosphere by Carlsson and Stein, for instance, depends in large part on balance between mechanical shockwave heating and the radiative cooling in the calcium lines. The calculations presented by Uitenbroek show that the radiative cooling estimates can be considerably in error if CRD is used for the calcium lines, as is done currently by Carlsson and Stein, instead of the more physically realistic PRD approach. Another addition to the code is the capability to perform non-LTE calculations of all four Stokes components of the radiation field in the presence of magnetic fields. With K.S. Balasubramaniam at Sac Peak, Uitenbroek has obtained spatially and temporally resolved observations of the Ca II 854.2 nm line. The full Stokes capability of the transfer code will be employed to analyze these observations, which which hold the potential to improve the estimate of chromospheric magnetic field strengths.

Future Research Plans

In the coming year, Uitenbroek plans to continue research on CO line formation using infrared spectroscopy and radiative transfer modeling. He plans to extend 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. Uitenbroek will attempt to improve the modeling of molecular line formation by including the effects of finite formation and dissociation rates on molecular concentrations. Uitenbroek will also further extend his numerical code to include the effects of PRD with cross redistribution (XRD), in which photons can scatter coherently from one line to the other. Preliminary calculations have shown that XRD is important for the formation of the diagnostically important O I triplet lines at 130 nm. The numerical Stokes code will be used 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.

<u>Service</u>

Uitenbroek is PI of the infrared camera effort at the Dunn Telescope in Sac Peak. He also oversies 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 TL-RBSE.

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 2002 facilities maintenance projects at each site are described below.

Sacramento Peak

The FY 2002 NSO/SP budget includes approximately \$25K 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 \$50K. Most of the General funds will be used to rehabilitate our above-ground water tank. The housing revenue funds will be used to upgrade permanent and visitor housing including upgrading a visitor quarters for compliance with the American's with Disabilities Act. In addition, the Long Range Plan lists as other maintenance tasks the demolishing of the Cloudcroft facility/RCA building. This is an item that has been carried forward for several years. Although important, funding availability and priorities have not allowed completion of this item. We will continue to monitor this situation and will accomplish this task whenever possible.

(Donars in Thousands)	
Project	Est Cost
Water Tank Rehab	\$ 25
Water Tank Cathodic Protection	10
Commercial/Telescope Painting	10
Housing Upgrades	20
Cloudcroft Facility/RCA Building	*50
Demolishing	
Total	\$ 115

Table E-1.	NSO-Sac Peak Summary of FY 2002 Projects
	(Dollars in Thousands)

* = FY 2001 year-end funds if available

Overhead Water Tank Rehabilitation: In the past year the overhead water tank has been evaluated by an outside contractor. It was found to need the interior sandblasted and recoated as the current coating

has delaminated on approximately 75% of the tank. Failure to recoat will cause excessive deterioration due to corrosion and oxidation.

Overhead Water Tank: The overhead water tank at Sac Peak is an unlined steel tank, which is susceptible to deterioration due to rust. A cathodic protection system can be installed which will protect the tank from deterioration. If this deterioration is not curbed the life expectancy of the tank will be reduced.

Commercial/Telescope Painting: A variety of commercial and telescope building require painting. These include the Main Lab, Hilltop Telescope and the Evans Solar Facility. This is a multi-year project.

Cloudcroft Facility: NASA spent over \$175K in renovation of the main telescope building at the Cloudcroft Telescope Facility. Other buildings, in particular the RCA building, are in poor condition and require attention. The RCA Building will cost approximately \$50K to demolish. This will remove an ongoing maintenance and potential safety problem.

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.

(Dollars in Thousands)	
Project	Est. Cost
McMath-Pierce electrical upgrade	\$ 30
McMath-Pierce painting	15
Re-roofing and sealing	5
McMath-Pierce fall protection	5
Total	\$ 50

Table E-2. NSO-Kitt Peak Summary of FY 2002 Projects (Dollars in Thousands)

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.

National Solar Observatory FY 2000 Telescope Usage Statistics

A. *Number of Observing Runs Using NSO Facilities:

Quarter	FY00
1 (Oct – Dec)	45
2 (Jan - Mar)	46
3 (Apr – Jun)	35
4 (Jul – Sept)	37
TOTAL	163

*Includes NOAO/NSO	staff projects
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- B. Total number of unique science projects: 81
- C. Users by Category:

	VISITORS			NOAO/NSO STAFF	
	U.S.	Foreign	Total	%Total	
PhDs	50	21	71	85.5%	18
Graduate Students	3	5	8	9.6%	-
Undergraduate Students	2	0	2	2.4%	-
Research Technicians	1	1	2	2.4%	10
TOTAL	56	27	83	100.0%	28

D. **Institutions Represented by Visiting Users:

	U.S.	Foreign	Total
Academic	17	13	30
Non-Academic	11	3	14
Total Academic & Non-Academic	28	16	44

**Note: Total number of institutions represented by users do not include departments or divisions within an institution as separate entities (e.g., US Air Force and NASA are each counted as 1 institution even though several different sites/bases/centers are separately listed in the data base.

E. Number of Visitors by Nationality:

Australia	1	Ireland	1
Canada	3	Italy	4
France	7	China	1
Germany	4	Norway	1
India	2	Switzerland	3

US Institutions:

American Institute of Physics California State University, Los Angeles, California State University, Northridge Cambridge Research and Instrumentation, Inc. College of William and Mary Connecticut College Cornell University Dickinson College East Carolina University Edinboro University Helio Research High Altitude Observatory, NCAR Jet Propulsion Laboratory Montana State University NASA Goddard Space Flight Center NASA Johnson Space Flight Center NASA Langley Research Center

Foreign Institutions:

Australian National University University of Calgary University of Waterloo Chinese Academy of Sciences Observatoire de Pic-du-Midi Institut d'Astrophysique de Paris (CNRS) Institut d'Astrophysique Spatiale, Orsay Astrophysikalisches Institut Potsdam Kiepenheuer Institut für Sonnenphysik Indian Institute of Astrophysics Queen's University Universita "La Sapienza", Rome Osservatorio Astronomico di Padova Universita di Padova, Dept di Astronomia University of Oslo ETH, Zürich

NASA Marshall Space Flight Center National Oceanic and Atmospheric Administration Naval Research Laboratory New Jersey Institute of Technology/Big Bear Solar Observatory Prairie View A & M University Southern Illinois University, Edwardsville Southwest Research Institute Tennessee State University University of Arizona University of California, Berkeley University of Hawaii, Institute for Astronomy University of Wisconsin, Madison U.S. Air Force OSUDRE, Falcon AFB U.S. Air Force Research Laboratory, Hanscom AFB Williams College

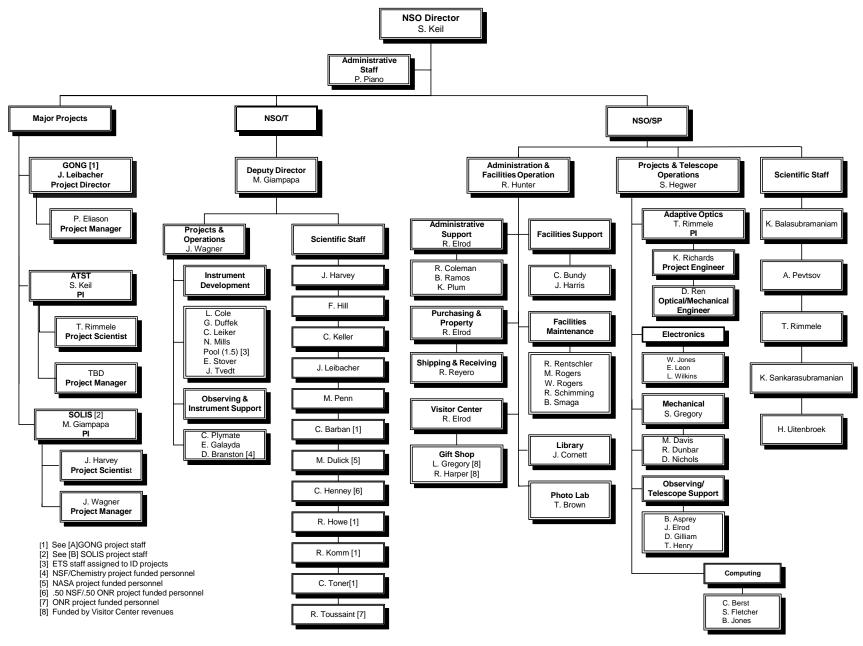
APPENDIX G: NSO MANAGEMENT

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

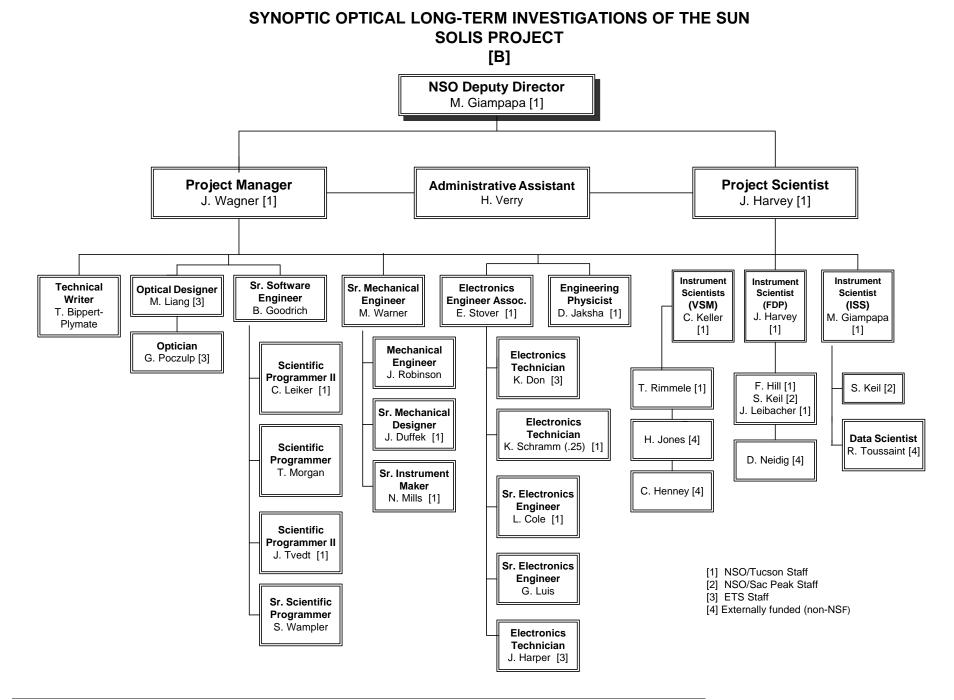
NOAO Managers Who Provide NSO Program Support

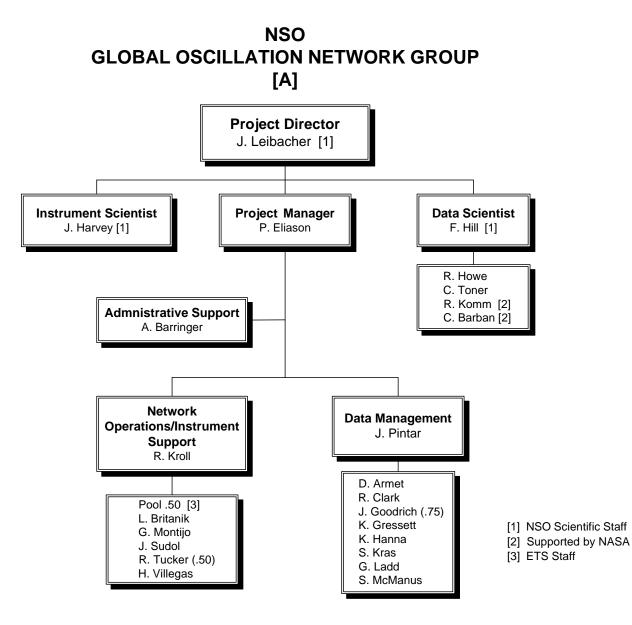
Larry Daggert	Manager, Engineering and Technical Services (ETS)
Steve Grandi	Manager, Central Computer Services (CCS)
Larry Klose	Manager, Central Administrative Services (CAS)
Sandra Abbey	Human Resources Manager
Patrick Phelan	Financial Manager
James Tracy	Controller
John Dunlop	Manager, Central Facilities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

NATIONAL SOLAR OBSERVATORY



Appendix H - 1 NSO Provisional Program Plan FY 2002: Organizational Charts





APPENDIX I: ACRONYM GLOSSARY

AASC	Astronomy and Astrophysics Survey Committee
AAS	American Astronomical Society
AFRL	Air Force Research Laboratory
AGU	American Geophysical Union
AO	Adaptive Optics
ARs	Active Regions
ASP	Advanced Stokes Polarimeter
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
CRD	Complete Frequency Redistribution
CSUN	California State University, Northridge
CY	Calendar Year
DHS	Data Handling System
DMAC	Data Management and Analysis Center
DoD	Department of Defense
DST	Dunn Solar Telescope
ESF	Evans Solar Facility
ESO NTT	European Southern Observatory New Technology Telescope
ETH-Zürich	Eidgenössische Technische Hochschule- Zürich
FDP	Full Disk Patrol
FP	Fabry-Perot
FTS	Fourier Transform Spectrometer
FY	Fiscal Year
GB	
	Giga Bytes Clabel Oscillation Naturals Crown
GONG	Global Oscillation Network Group
GOLF	Global Oscillations at Low Frequencies
GSFC	Goddard Space Flight Center
HAO	High Altitude Observatory
HESSI	High Energy Solar Spectroscopic Imager
High-QE	High-Quantum Efficiency
HT	Hilltop Telescope
IAC	Instituto de Astrofisica de Canarias
IR	Infrared
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
LAN	Local Area Network
LTE	Local Thermal Equilibrium
LMT	Liquid Mirror Telescope
MDI	Michelson Doppler Imager
MHD	Magnetohydrodynamic

APPENDIX I: ACRONYM GLOSSARY

	Mission Operations & Data Analysis (NIASA)
MO&DA MRI	Mission Operations & Data Analysis (NASA)
NAS	Major Research Instrumentation (NSF)
NAS	National Academy of Sciences
	National Aeronautics and Space Administration
NJIT No a a	New Jersey Institute of Technology
NOAA	National Oceanic and Atmospheric Administration
NOAO NOAO/ETS	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
OCS	Observing Control System
PAEO	Public Affairs and Educational Outreach
PCA	Principal Component Analysis
PRD	Partial Frequency Redistribution
PSPT	Precision Solar Photometric Telescope
RBSE	Research-Based Science Education
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RISE	Radiative Inputs of the Sun to Earth
SCOPE	Southwest Consortium of Observatories for Public Education
S-DIMM	Solar Dual Image Motion Monitors
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
SRA	Summer Research Assistant
STEREO	Solar Terrestrial RElational Observatory (2 spacecraft)
ТВ	Tera Bytes
TCS	Telescope Control System
TRACE	Transition Region and Coronal Explorer
UV	Ultraviolet
VMG	Vector Magnetograph
VSM	Vector Spectromagnetograph
VSO	Virtual Solar Observatory
WWW	World Wide Web
XBP	X-ray Bright Points
XRD	Cross Redistribution
Yohkoh	"Sunbeam," Satellite project of the Japanese Institute of Space and Astronautical Sciences
ZIMPOL	Zürich IMaging POLarimeter