NATIONAL SOLAR OBSERVATORY

Provisional Program Plan FY 2001



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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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NSO has embarked on a multi-year program to renew its assets and invigorate solar physics in the US. 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; completing and operating the instruments comprising the Synoptic Optical Long-term Investigation of the Sun (SOLIS); upgrading the Global Oscillation Network Group (GONG) cameras from 256^2 to 1024^2 pixels (GONG++); 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
 - Space weather and terrestrial effects
- Exploring the unknown
 - Fundamental plasma Magnetic field processes

We are encouraging broad community involvement in our programs by developing partnerships with universities, HAO, other government agencies, industry and foreign institutions. Recent examples include an alliance with 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 to develop high-order solar adaptive optics, and participation of several universities (Hawaii, Michigan State, Montana State, NJIT, Caltech, Rochester, Chicago, Colorado, Cal State Northridge, UCLA, UC-San Diego, Stanford, Harvard, and Princeton), HAO, NASA Marshall Space Flight Center (MSFC), the Naval Research Laboratory (NRL), and Lockheed Palo Alto Research Laboratories in development of the ATST concept. We are also discussing a second SOLIS site to be developed and operated by IAC on Tenerife. We will continue working closely with the Air Force, NASA and NOAO to provide critical synoptic observations that, in addition to producing their own noteworthy science, also support space and other ground-based observations.

This program plan presents in detail what NSO proposes to accomplish in FY 2001 with its base funding of \$8.1M, which is the amount proposed in the budget submitted by the President to Congress. In addition, we discuss how the program will be broadened to incorporate incremental funding that is

being proposed for a part of the NSO and community program to develop a large-aperture solar telescope.

The NSO plan specifically includes: (1) completion and operation of SOLIS using NSF construction funds and base support as needed; (2) upgrade of GONG to GONG++ with incremental funding, and operation of GONG++ with incremental and base-funding; (3) increased investment in adaptive optics (AO) through incremental funding and continued base-funding support; (4) development of other ATST technologies and site testing using base and incremental funding; (5) operation of flagship facilities until ATST is on-line out of the base; and (6) operation of other facilities as supported by our partners.

NSO has developed a program that is highly invested in the future need for a healthy US ground-based 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 IR technologies in solar physics. The McMath-Pierce is the premier facility for infrared 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 (ASP) at the DST, IR and ZIMPOL 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. The 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 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.

The Roadmap below shows how the NSO facilities will evolve over the next 10 years. During FY 2002, NSO plans to replace many of its existing synoptic programs with SOLIS. RISE/PSPT began operations in 2000 and will continue in FY 2001. Operation of GONG, with the enhanced resolution provided by the 1024^2 cameras, will begin in FY 2001, and work will continue on the NSO digital library. Working closely with the solar community, NSO will begin the concept and development phase for the ATST, including the 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 2005.



Initiatives

Advanced Technology Solar Telescope (ATST)

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 0.1 arcsec 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 two 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 on page 5. NSO will lead a community-wide effort that includes HAO and a broad and diverse university base to submit a proposal to NSF for a concept and design phase beginning in FY 2001. FY 2001 will begin with 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 investment of its current and expected resources to developing 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 if a coronal option is chosen, frequent coronal skies. In order to perform a quality site evaluation and selection for the ATST, an ATST Site Advisory Committee will be formed. This group will define and oversee the ATST siting activities and ultimately recommend the siting of the ATST. This committee should represent all participating nations in case the ATST becomes an international project, and should agree upon the definition of relevant site properties, methods of measuring these properties, and criteria to be used for site selection. Facilities needed to carry

out the measurements (solar dual image motion monitors (S-DIMMs), scintillometers, sky photometers, PWV meters, imaging systems, etc.) need to be agreed upon and constructed as early as possible. Over the past few years, NSO has conducted an exploratory site-testing program using scintillometers, and currently is building an improved sensor based on a solar dual image motion monitor. Working with the advisory committee, NSO will calibrate and employ the S-DIMM to measure seeing at NSO/SP over the next few months, and will collaborate with other observatories to identify a suitable site.



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; scheduled for a January 2001 launch), STEREO (2004) and the Japanese SOLAR-B (2005) missions 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 three-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. 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 frequent improvements to SOLIS during its 25-year operational life.

In its discussion of small initiatives to be pursued, the recent NAS/NRC decadal Astronomy and Astrophysics Survey Committee report explicitly mentions the possibility of a network of SOLIS vector spectromagnetographs being built to enable nearly continuous observations. Such a network would provide the major data input for the Solar Magnetic Initiative (SMI) proposed by HAO and several universities with the goal of strengthening solar magnetic modeling and theory. NSO will seek ways to comply with this community recommendation by proposing to construct duplicate instruments to be sited at two widely different longitudes in addition to the first site.

GONG++

The Global Oscillation Network Group (GONG) Project 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.

GONG will continue to 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 will be replaced with 1024×1024 square pixel ones [an upgrade known as GONG+] by 2001, which 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 original GONG system interrupted observations once per hour in order to obtain a magnetogram, which introduced periodic gaps in the helioseismic data. To overcome this noise source, the GONG+ system will leave the magnetogram modulator in the optical path permanently and thus, as a by-product, make available full-time surface magnetic field measurements. The current, low spatial resolution magnetograms have already proven 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. The GONG+ operations will require an additional \$0.25M/year beginning in FY 2001, to keep up with the factor of 32 increase in data flow, and the subsequent increase in data storage media and processing.

The GONG+ system will capture data from the 1024×1024 camera and perform rudimentary quality assessments, but will not be able to provide high-spatial resolution helioseismic data to the community. 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 remapping 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 \$1M, and the annual operating costs will be about \$0.5M higher than the amount already contained within the budget for operation of the GONG+ network.

Instrumentation Program

Adaptive Optics

The NSO adaptive optics system is now used routinely at the DST to obtain high-resolution observations of solar fine structure. A significant number of observing runs have been carried out by NSO staff and visitors. The AO system has been used with a number of post-focus instruments available at the DST, such as the Advanced Stokes Polarimeter (ASP), the Universal Birefringent Filter and the dual Fabry Perot system. User supplied instruments, such as ZIMPOL (ETH) and a speckle camera (KIS) were successfully integrated with the AO system. These observing runs have provided several users of the DST with data of unprecedented quality. For example, the first time sequences of diffraction-limited images and magnetograms of magnetic flux tubes were produced. Movies of these data as well as other diffraction-limited images can be viewed at <u>www.sunspot.noao.edu/AOWEB</u>.

Following a request by the Kiepenheuer Institute, the NSO AO system was shipped to the Canary Islands (Tenerife), where it was successfully operated at the German VTT. A large number of scientists from various institutions in Germany have used the AO system for a number of different science projects during this 3-month observing campaign. Data supporting two PhD theses were generated. The New Jersey Institute of Technology/Big Bear Solar Observatory has asked to perform a similar campaign at their telescope.

Some of the post-focus instrumentation at the DST was designed for seeing-limited resolution, e.g., the Advanced Stokes Polarimeter, one of the most productive instruments at the DST, has a pixel resolution of 0.4 arcsec compared to the diffraction limit of about 0.2 arcsec. In collaboration with HAO, NSO is designing a diffraction-limited stokes polarimeter to be installed permanently at the DST. The polarimeter will take advantage of new CCD technology which provides high quantum efficiency at high read-out rates. This will allow diffraction-limited observations of the vector field with both high sensitivity and good time resolution.

NJIT/BBSO, NSO, AFRL and KIS have just started an NSF-MRI funded program to develop three highorder AO systems. Each system is based on a Shack-Hartmann wavefront sensor with 76 subapertures and will, for example, provide diffraction-limited imaging at the DST during median seeing conditions. The development of high-order AO is also an important technology development step toward an even bigger AO system for the Advanced Technology Solar Telescope. The prime requirement for the ATST is diffractionlimited resolution. The availability of a functioning solar adaptive optics system and the experience gained from its operation are crucial for the successful implementation of the ATST. The AO program will now concentrate on achieving the following milestones:

AO Milestones	Timing
- Continue to improve performance user-friendliness of low-order AO system	FY 2001
- Continue AO science runs at the DST	FY 2001+
 Design and construction of diffraction-limited, high-QE polarimeter; collaboration with HAO 	FY 2001 - 2002
- Continue design and construction of high-order AO system (NSF-MRI)	FY 2000 - 2002
- Implement high-order AO at DST and conduct science experiments	FY 2003+
 Perform high-order AO experiments at telescopes of larger aperture (McMath [IR], Canary Islands) 	FY 2003+

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. Negotiations are underway for the procurement of a camera controller and cryogenic enclosure.

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.

Spectral Hole Burning Device

While CCDs are currently the imaging detectors of choice for optical astronomy, there are concepts for advanced technologies that will provide important new capabilities for developing future astronomical instruments. In spring 2000, NSO submitted a proposal to NASA's cross-disciplinary program to develop a

revolutionary detector. If funding becomes available in FY 2001, a three-year program to develop a highlywavelength-sensitive imaging detector will begin. The detector consists of organic dye molecules in an amorphous plastic film that is cooled to 1.4K. This cryogenic film acts like a superb color slide film with a spectral resolution comparable to the best available spectrographs and a spatial resolution that surpasses that of CCDs. No dispersing elements or filters are needed to obtain spectral information. The basic process employed in this detector scheme is persistent spectral hole burning, which explains the name given to this technology.

An initial technology demonstration experiment imaged the solar rotation velocity field with a single exposure of the device and provided spectra of hundreds of lines at every spatial location. If NASA funding becomes available, an astronomical camera based on these principles will be built and used to image astronomical objects and demonstrate its usefulness for hyperspectral remote sensing of the Earth.

FTS Imager

The purpose of this study is to determine the feasibility of upgrading the McMath-Pierce Fourier Transform Spectrometer to a full high-resolution FTS imager. The first stage will focus on comparing the performance of a mercury-cadmium-teluride (MCT) array detector to a single-element detector by using the Sun as the extended source. Here the aim is to quantitatively demonstrate whether or not a significant enhancement in the signal-to-noise ratio of extended-source spectra can be achieved with a MCT array detector. The MCT array detector chosen for this comparison is the KPNO NICMASS camera, a 256×256 pixel imager that operates in the 1-to-2 micron spectral range and has a readout rate on the order of a few Hz. Because of its slow readout rate, the comparisons will be limited to relatively low-resolution spectra (resolving powers less than or equal to 50,000). Nevertheless, the results should be more than adequate to dictate the course for further investigations. Pursuing this study further would require achieving an enhancement factor of 5 or better. If this turns out to be the case, then the next logical step would be to repeat the comparison with a commercially available InSb array detector that has a much faster readout rate (500 Hz) in order to record spectra at the maximum resolution of the McMath-Pierce FTS instrument (Doppler-limited resolving power of 800,000 at 1 micron).

SUPPORT TO PRINCIPAL INVESTIGATORS AND THE SOLAR-TERRESTRIAL PHYSICS COMMUNITY

NSO Telescope Operations and Upgrades

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.

NSO/Sacramento Peak

• Dunn Solar Telescope

The 76-cm Dunn Solar Telescope is located on Sacramento Peak at an altitude of 2804 m. 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; high-speed correlation trackers to remove image motion and jitter; and most recently, a low-order adaptive optics system that gives diffraction-limited telescope performance under good seeing conditions. With the advent of adaptive optics correction, it is again the world's premier high-resolution solar telescope, containing a wealth of focal-plane instrumentation. A high-order system that will provide diffraction-limited seeing under moderate to poor conditions is being developed. Recent discoveries at the Dunn solar facility include:

- Locations where the p-modes are excited.
- Origin of the Evershed flow.
- The existence of twisting flows prior to solar flares and coronal loop ejections.
- Observations of magnetic reconnection in the chromosphere.
- Sub-arcsecond convective motions inside magnetic pores.
- The existence of weak granular fields.
- Oscillatory magneto-convection.
- First prominence magnetic field measurements.

• Adaptive Optics

The NSO adaptive optics project continues to make remarkable progress. The low-order system is now available for all users on a shared-risk basis. Collaborations with the AO group are strongly encouraged.

• Advanced Stokes Polarimeter

The joint HAO/NSO Advanced Stokes Polarimeter remains available to users, and can now be fed with the adaptive optics system. NSO and HAO plan a collaboration to upgrade the ASP to match the full resolution of the DST as provided by the AO system.

• Fast CCD Cameras

Two Spectral Instruments $1K \times 1K$ CCD cameras were recently purchased and will be available to users in FY 2001. The site detectors are thinned back-illuminated, providing outstanding quantum efficiency. The readout rate is 850 kHz with data recorded to DLT, hard disk or exabyte.

• Dual Fabry-Perot Filters

The dual Fabry-Perot (FP) filter system for visible wavelengths is nearly complete and will become available to users during FY 2000. This system combines a 60 mÅ passband and a <20 mÅ passband FP with a set of narrow (3 – 4 Å) blockers to provide a tunable narrow band filter with high transmission, capable of tuning at very fast speeds.

A second narrow-band filter optimized for the near infrared from $1.1 - 1.7 \mu m$ is currently available for users. It consists of two 50-mm aperture Fabry-Perot Etalons in tandem, which can be tuned from about 1.1 to 1.7 μm . One of the FPs is used as an order selector with a full width at half maximum (FWHM) of 1.7 Å and a free spectral range of 39.4 Å at 1.56 μm . The second FP provides narrow-band imaging. It has a FWHM of 113 mÅ and a free spectral range of 5.225 Å. The order-selecting and narrow-band Fabry-Perots have transmissions of 83% and 78%, respectively. We also have a blocking filter with a 47.6 Å FWHM centered on 1.5652 μm and a transmission of 91%. The system has been combined with polarization optics and the NSO near-IR cameras to obtain weak-field vector magnetograms.

• Evans Solar Facility

The Evans facility provides a 40-cm coronagraph as well as a 30-cm coelostat. The Evans coronagraph is the largest in the United States 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). Recent instrumentation includes a visible and IR coronal polarimeter which has produced tantallizing observations of coronal magnetic fields. This new instrumentation will provide core capabilities for the next generation of ground- and space-based coronal telescopes. The Evans also provides full-disk spectroheliograms in several bandpasses near the Ca II K-line and H α . These observations will be replaced by SOLIS so there are no plans to upgrade these capabilities.

• 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 coleostat 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 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 (PSPT) project consists of 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. A data center has been established at HAO to process the images from these telescopes. 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. FY 2000 witnessed commissioning of the third RISE/PSPT telescope, which is now operating at NSO/SP. The other two telescopes forming the PSPT network are in Hawaii (operated by HAO) and Italy (operated by the University of Rome). NSO will seek funds to operate the PSPT for at least a full eleven years to provide data for all phases of the solar cycle.

NSO/Kitt Peak

The McMath-Pierce main telescope on Kitt Peak, at an altitude of 2096 m, is the largest unobstructedaperture 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 East and West Auxiliary telescopes are among the largest solar telescopes and share the same all-reflective, unobstructed design of the main telescope. The light path is thermally controlled to minimize internal seeing. The large light-gathering power, the extended wavelength range from the UV to the far IR, and the well-behaved polarization characteristics of the telescopes make them unique instruments and have stimulated extensive solar and nighttime research. The McMath-Pierce facility is scheduled for observing for more hours than any of the large NOAO telescope because it is used both day and night. The existing post-focus instruments are state-of the-art. The Fourier Transform Spectrometer is a unique national resource in wide demand by atmospheric physicists and chemists, as well as astronomers. Recent discoveries at the McMath-Pierce facility include:

- Fine structure in sunspot penumbrae at 0.1 arcsec spatial resolution in the visible.
- Evershed flow in weak, cool magnetic fields in sunspots seen in Ti lines at 2.2 μm.
- Cool cloudlets in the solar chromosphere due to convective overshooting seen in CO at 4.7 μm.
- Quantum interference between fine-structure components seen in coherent scattering polarization.
- Spatial variation of solar background magnetic field from Hanle effect measurements.

• 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.

• East Auxiliary Upgrade

This upgrade will include replacement and/or repair of the East Auxiliary heliostat RA and Dec drives, control system upgrades, and the addition of a CCD camera for the telescope. An image rotator along with an auto-guiding system will also be provided. The East Auxiliary upgrade costs of approximately \$150K are funded by NASA as part of their Astrometric Follow-up Studies of Near-Earth Asteroids program.

• Seeing Improvement

Tests of potential improvements to the telescope seeing are underway. These tests will provide information which will aid in designing the ATST. The tests include placement of fans at the location of the 1.52-m primary in order to introduce a laminar air flow over the mirror. It is expected that both mirror heating and turbulence formation immediately above the mirror will be mitigated and, hence, improve the seeing quality. In addition, the heliostat mirror supports and mirror figures are being investigated as potential sources of telescope-induced degradations of the seeing. Ultimately, a wavefront sensor must be installed to achieve an improved understanding of the site seeing characteristics.

• Adaptive Optics

Following development of a successful AO system at the Dunn Solar Telescope, testing of an AO system at the McMath-Pierce telescope will commence. In this way, the McMath-Pierce can serve as one possible test-bed for an AO system at a large-aperture telescope.

• Kitt Peak Vacuum Telescope (KPVT)

This facility will not be upgraded since it will be replaced by SOLIS.

Telescope and Instrument Combinations FY 2001

Key: DST = Dunn Solar Tel.; ESF = Evans Solar Facility; HT = Hilltop Tel.; KPVT = Kitt Peak Vacuum Tel.

Instrument	Telescope	Comments/Description				
NSO/Sacramento Peak – OPTICAL IMAGING & SPECTROSCOPY						
Low-Order Adaptive Optics	DST	20-mode correction				
Advanced Stokes Polarimeter (ASP)	DST	Photospheric/chromosphericvector polarimetry, visible, 0.375 arsec/pix				
Universal Birefringent Filter (UBF)	DST	Tunable narrow-band filter, $R \leq 40,000, \ 4200$ - $7000 \ {\rm \AA}$				
UBF-FabryPerot	DST	Tunable narrow-band filter, $R \leq 250,000,\ 4200\ \text{\AA}$ - $7000\ \text{\AA}$				
Dual-FabryPerot	DST	Tunable narrow-band filter, R \leq 250,000, 4200 Å $-$ 7000 Å, high transmission				
Horizontal Spectrograph	DST	$R \le 500,000, \ 300 \ nm - 2.5 \ \mu m$				
Echelle Spectrograph	DST	$R \le 2,000,000,~300~nm$ - 2.5 μm				
Universal Spectrograph	DST/ESF	Broad-spectrum, low-order spectrograph, flare studies				
Littrow Spectrograph	ESF	$R \leq 1,000,000,~300~nm$ - 2.5 μm				
Various CCD Cameras	DST/ESF/HT	380 - 1083 nm, Formats: 256×256 to $2K \times 2K$				
High-Speed Polarimetric Camera	DST/ESF	380 – 1083 nm, 1K × 1K				
Correlation Tracker	DST	Tip/tilt correction				
40-cm Coronagraph	ESF	300 nm – 2.5 μm				
Full-Limb Coronagraph	HT	Emission-line coronagraph				
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å				
Flare Patrol	HT	H- α and white-light full-disk images, 1 min. cadence				
NSO/Sacramento Peak –IR IMAGING	& SPECTROSCOPY					
Horizontal Spectrograph	DST	High-resolution 1 - 2.5 μm spectroscopy/polarimetry, R \leq 300,000				
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 µm spectroscopy/polarimetry				
IR Dual Fabry Perot VMG	DST/ESF	Narrow-band imaging and vector magnetograph, 1 - 2.5 $\mu m, R$ $\leq 200,000$				
NSO/Kitt Peak – IR IMAGING & SPEC	CTROSCOPY					
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 μ m, 256 × 256, 12 Hz, imaging spectroscopy, polarimetry				
CCD Cameras	McMath-Pierce	380 - 1083 nm, 576 × 384				
ZIMPOL II	McMath-Pierce	450 – 1100 polarimetry, 5 Hz, 800 × 1200				

Data Management

NSO maintains an extensive digital library, which currently contains about 250 GB of solar data distributed over magnetic disks and a CD-ROM jukebox system. The data holdings comprise:

- The entire Kitt Peak Vacuum Telescope (KPVT) synoptic data set of full-disk solar magnetograms and Helium 1083-nm spectroheliograms from 1974 to the present.
- The entire Fourier Transform Spectrometer (FTS) data set of high-resolution spectra and interferograms of solar, stellar, planetary, terrestrial atmospheric, and laboratory sources.
- Recent full-disk solar spectroheliograms in Ca K and H-alpha from the NSO/Sac Peak Evans facility.

All of these NSO data are on-line and accessible through a web-browser user interface to a searchable relational data base management system (RDBMS). The URL is *http://www.nso.noao.edu/diglib*.

In addition, NSO/T maintains the 6-TB GONG helioseismic data set, which is stored off-line on 8-mm tape. The web servers for GONG and NSO/T have now been integrated on a single machine. GONG data can be accessed at *http://www.gong.noao.edu/dsds/query.html*.

Development of the NSO digital library has currently stopped due to a lack of funds. In response to the NAS/NRC decadal AASC endorsement of a National Virtual Observatory (NVO), NSO has drafted a white paper for a "Virtual Solar Observatory" (VSO) that would federate many solar archives.

SOLIS will have a major impact on the NSO digital library. The core science programs will produce data at the rate of over 30 GB per day and are expected to total nearly 100 TB over the 25-year lifetime of the instrument. In addition, it is conceivable that some intensive PI programs could operate the full suite of instruments at their maximum rate, which would produce 240 GB in a single day. These prodigious rates, along with the requirement to allow data access over the Internet within 10 minutes of collection, cannot be handled without substantial hardware upgrades, both to the data link connecting Kitt Peak with downtown and the NSO digital library.

The data link is now being upgraded to DS-3 capacity to handle the maximum volume of SOLIS data production, thanks to an NSF grant. The Digital Library hardware will also be substantially upgraded, and we anticipate installing a mixture of optical disk (probably DVD jukeboxes), magnetic disk (large RAIDs), and high-capacity tape (DLT jukeboxes) systems to handle (at least partially) the storage of the core science data.

Scientific Staff

NSO currently has 13 PhDs on its staff, six in Tucson, six in Sunspot and one in the director's office. In addition, in Tucson there are two NASA-funded PhDs working on GONG, one NSF/Chemistry-funded PhD working with the FTS, and one ONR-funded PhD working on SOLIS. There are three AF funded PhDs working in Sunspot. The research strength of the staff is reflected in the fact that staff members have won the last two Hale Prizes of the AAS. The major strength of the NSO staff, however, has been and still is its strong and creative instrumental capability.

Maintaining a strong scientific staff is critical to providing US solar physicists with the best solar facilities in the world. This is a major challenge for NSO, given the extremely limited resources available for the type of staff R&D that leads to major technological breakthroughs. While NSO has obtained funds over the last decade for a few major projects (GONG, SOLIS, AO and ISOON) that service the solar community, the projects also involve major commitments of staff time to develop and operate. This in turn limits staff time to pursue their research. By concentrating the limited, NSO-controlled project funds on only two projects, AO at NSO/SP and IR technologies at NSO/T, we have made major breakthroughs in these areas. Staff members wishing to pursue other areas have not had internal resources to use. Over the next several years, NSO resources will be devoted to developing the ATST and technologies needed to make it work. NSO staff will be involved in all phases of ATST development which will continue to distract from the time available for research.

Higher 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 (five in Tucson and three at Sac Peak) and four graduate students (one in Tucson and three at Sac Peak). This year, for the first time, through supplemental funds provided by NSF to support teachers' participation in the REU program, NSO is participating in the summer 2000 Research Experiences for Teachers (RET) program. Two high school science teachers, one at Sac Peak and one in Tucson, are working with NSO staff scientists.

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 mentor 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.

Through the NSF Research Experiences for Teachers (RET) program, high school teachers at Sacramento Peak and in Tucson work with NSO staff scientists to develop classroom exercises based on NSO data that are available on the WWW. NSO personnel also participate in the NSF-funded teacher enhancement program, *The Use of Astronomy in Research-Based Science Education* (RBSE). For the past seven years, NSO has participated in the New Mexico Summer Teacher

Enrichment Program (STEP), which provides New Mexico teachers the opportunity to work in a research environment and material they can use in their classrooms.

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, Whipple Observatory, and Lowell 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.

A wide range of interactive displays at the Visitor Center is nearing completion. 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. 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. Upon completion of the displays, the possibility of charging an admission fee to the display area will be

evaluated as a source of additional revenue to further expand our public and educational outreach programs.

NSO Public Web Pages

The NSO WWW site 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

NSO recently became a programatically independent observatory managed by AURA, Inc. under contract to the NSF. NSO funding is still linked with, and services continue to be obtained from, NOAO. NSO is divided into two major divisions, NSO/Sacramento Peak (NSO/SP) and NSO/Tucson (NSO/T), with a project division, NSO/GONG. NSO also has two major project groups, one conducting SOLIS, which is funded by the NSF and one ISOON funded by the USAF. A new project office to oversee the ATST will be formed during FY 2001. NSO currently has 74 employees, including unfilled positions. An additional 29 employees work at NSO and its facilities who 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.

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 adaptive optics, support for SOLIS and development of the Improved Solar Observing Optical Network (ISOON) 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 polarimetery techniques that can take advantage of high-resolution facilities. Currently there are 52 personnel at NSO/SP. There are 36 permanent NSF-funded employees, 4 permanent AF scientists, 8 AF-funded NSO employees working on the ISOON project, and 4 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 polarimetery techniques, solar-stellar observation techniques, and speckle imaging techniques. NSO/T has 17 permanent NSF-funded staff, 5 NSO employees funded by SOLIS, and 4 funded by NASA and other sources working on data archiving and other projects.

NSO/GONG operates and maintains the GONG network of 6 telescopes, collects and processes the data, and makes the data available to users. In addition, GONG upgrades are designed and implemented. NSO/GONG currently has 19 NSO employees and 2 employees funded by NASA.

The NSO Director's office consists of two employees, the director (Dr. Stephen Keil) and his assistant (Priscilla Piano). The director currently maintains his residence at NSO/SP. A site director for NSO/T (Dr. Mark Giampapa) also serves as deputy director. The director spends at least one week a month in Tucson. NSO/SP has a site administrator (Rex Hunter) to take care of operations and facilities. In addition, the NSO director shares support personnel with the NOAO for accounting, human resources, graphics, educational outreach etc.

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 2001 Spending Plan

The NSO base budget received from NSF in FY 2000 was \$6.8M, including \$1.4M specifically for SOLIS development. In addition, another \$1.1M of the NSO budget is embedded in the NOAO program in terms of services and support and \$154K goes to AURA as a 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.

The SOLIS funding wedge of \$1.4M becomes available in FY 2001 as SOLIS is completed and enters its operational phase. Under current plans, NSO will retain \$1.1M of this wedge to invest in SOLIS operations, GONG upgrades, and ATST development. Thus the NSF base funding for NSO in FY 2001 is \$6.5M. We anticipate receiving the same level of services and support from NOAO and KPNO.

We have developed the following program, assuming a base funding level of \$6.5M. In addition, NSO has proposed to the NSF/Major Research Instrumentation (MRI) program in collaboration with NJIT/BBSO and the Kiepenheuer Institute to support the development of high-order adaptive optics. NSO will also submit a design and development phase proposal to NSF to begin ATST technology studies and design efforts. We present our program incrementally to reflect different funding levels, depending on the success of these proposals. Some of the incremental funding for the ATST would be spent in the community.

Table 1. NSO Base Funding – (Dollars in Thousands)	- FY 2001
	NSF Base
NSO Director's Office	208
NSO/Tucson	1,103
NSO/SP	1,452
NSO/GONG/GONG+	2,201
NSO/ATST	1,066
NSO/SOLIS	480
Total Spending – NSF	\$6,510

Table 1 shows the portion of the NSO base funding allocated to major programatic elements of the NSO program.

Base funding spent in Tucson and Sac Peak in support of telescope operations and science programs are grouped separately under the headings NSO/Tuscon and NSO/SP. Because the scientific staff is heavily involved in the ATST, SOLIS and GONG, a substantial portion of these funds also support those programs. Chart A shows the percent of the NSF base funding being spent in each program element.



Chart A. NSO Base Funding

The spending break down for each category is shown in the following Tables 2-5. The director's office non-payroll includes funds for committee travel.

Table 2. NSO Director's Office Base Funding FY 2001				
(Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
Staff	203	23	226	
Committees		10	10	
Budgeted Indirects			(18)	
Total Spending – NSF	\$203	\$33	\$218	

Some of the instrument-development labor and non-payroll funding spent from NSO/Tucson and NSO/SP budgets have been transferred into the ATST and SOLIS accounts to show how those funds are actually being spent.

Table 3. NSO/Tucson Base Funding FY 2001						
(Dollars in Thousands)						
Payroll Non-Payroll Total						
Scientific Staff	674	43	717			
Software Support	153	10	163			
Instrument Development	21	6	27			
NOAO/ETS → NSO	101		101			
Telescope Operations	106	21	127			
NASA Support (32)						
Total NSO/Tucson \$1,055 \$80 \$1,103						

(Donars in Thousanas)				
	Payroll	Non-Payroll	Total	
Scientific Staff	499	30	529	
Scientific Support/Computing	210	103	313	
Instrument Development	228	36	264	
Telescope Operations	134	26	160	
Facilities	319	292	611	
Administrative Services	186	20	206	
Visitor Center	23	32	55	
Housing Revenue			(90)	
Meal Revenue			(16)	
AF Support			(432)	
Visitor Center Revenue			(50)	
Other Programmed Indirects			(98)	
Total NSO/SP	\$1,599	\$539	\$1,452	

Table 4. NSO/SP Base Funding FY 2001 (Dollars in Thousands)

GONG will transition from development of the GONG+ cameras to their operation. GONG will also begin acquiring hardware for the GONG++ full-up operations of the new high-resolution camera systems.

Table 5. NSO/GONG Base Funding FY 2001				
(Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
Scientific Staff	133	27	160	
DMAC Operations	542	115	657	
Instrument Development				
Telescope Operations	253	404	657	
Administrative Services	133	21	154	
GONG+ Operations	73	200	273	
GONG++ Hardware		300	300	
Total GONG \$1,134 \$1,067 \$2,201				

Table 6 shows the NSO investment in the ATST. The table assumes that the NJIT/NSO proposal to the NSF/Major Research Instrumentation (MRI) program for developing high-order, solar adaptive optics is funded. NSO will continue its AO investment from the base program, split between making the low-order AO system into a user-friendly system for routine observations at the Dunn Solar Telescope, and improving the performance of the Advanced Stokes Polarimeter to match the diffraction-limited imaging of the DST and the high-order AO system. The table also includes \$500K of the SOLIS wedge for developing ATST site-testing instruments and data analysis. NSO will also continue its investment in the IR camera technologies needed to use the ATST in the 1.0 - 35 micron wavelength range.

Table 6. NSO/ATST Base Funding FY 2001				
(Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
In-House AO Program	236	60	296	
High-Order AO – MRI	350	350	700	
IR Camera	100	90	190	
Site Testing	310	270	580	
NSF/MRI Proposal			(700)	
Total ATST	\$996	\$770	\$1,066	

SOLIS funding includes planned carryover from FY 2000 which reflects the fact that SOLIS began late in a fiscal year. Because of a delay in the delivery of the PixelVision camera, SOLIS will implement a contingency camera system, which requires a modest increase in cost. This will be covered from the SOLIS funding wedge.

Table 7. NSO/SOLIS Base Funding FY 2001				
(Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
Construction	698	1,302	2,000	
Construction In-House	230	200	430	
Operations	50		50	
Planned Carryover				
Carryover FY 2000→ FY 2001			(2,000)	
Total SOLIS	\$978	\$1,502	\$480	

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 while a proposal for the ATST is bing developed. NSO is also using its base funding to support SOLIS and AO. Given the need to maintain a US presence in solar physics and the goal of attaining an ATST, we prioritize our 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 we expect 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 we will:

- Curtail all base-funded project activities at NSO/SP not related to ATST development or SOLIS. Concentrate on AO, site testing, and telescope technology testing while aggressively seeking partners and funding for these activities. Delay, or put on hold, noncritical maintenance items.
- Curtail all other base-funded activities at NSO/T not related to SOLIS development and operations, or to ATST development. Concentrate on IR development and high-resolution imaging and spectroscopy in the infrared.
- Both sites would contribute scientific staff time to ATST development (AO, IR technology, and design). Unfilled positions would be used to recruit an ATST project engineer and technical personnel needed to test and evaluate ATST technology.
- Any other activities at NSO will need non-base (NASA, AF, NOAA, etc.) support or be dropped.
- 2. Complete SOLIS with current funding plus base support as needed. Operate SOLIS by devoting NSO resources currently used to operate and reduce data from the KPVT. NOAA and NASA will continue to provide operational support.
- 3. Continue operating GONG in 256 × 256 mode from base budget. Develop a proposal for funding GONG++ operations.
- 4. Operate the RISE/PSPT site at NSO/SP from base budget while other RISE sites are operated by HAO and the University of Rome with their own funds. Propose to NSF/ATM for RISE/PSPT maintenance funds.

Table 8 is a prioritized summary of how NSO would invest the \$1.1M SOLIS wedge that it will retain.

Priority	ltem	Cost	Notes
1	ATST Site Survey	\$500K	Build site-testing instruments
2	SOLIS	\$200K	Implement contingency plans; develop data analysis & archiving tools
3	GONG+	\$100K	Part of additional cost of operating GONG+
4	GONG++	\$300K	Begin hardware acquisition

 Table 8. NSO Investment of SOLIS Wedge

We will also devote resources from our base to implement this strategy. These include:

- Continuing in-house AO investment	\$296K
- Developing a large-format IR camera system	\$190K

 Finishing the S-DIMM prototype 	\$ 80K
 Completing SOLIS construction 	\$230K
 Assigning a SOLIS observer 	\$ 50K

None of these numbers include scientific staff time. With Rimmele fully engaged in AO and ATST development, Keller and Wagner on ATST proposal development, Uitenbroek and Keller working on the IR, Beckers and Hill on site surveys and telescope technologies, and Keil on ATST advocacy and community relations, the total NSO/base investment in ATST development is approximately \$1.2M (\$400K scientific salary+benefits + \$840K shop time and non-payroll).

ATST Proposal

Development and construction of a 4-m class Advanced Technology Solar Telescope (ATST) is the top ground-based priority of the solar physics community for the next several years. This priority was stated in both the decadal survey and the NAS/NRC report on "Ground-Based Solar Research: An Assessment and Strategy for the Future." The ATST will play a key role in US and international solar physics. The largest operating solar telescope is the McMath-Pierce with a 1.5-m aperture. The ATST represents a major step in solar telescope technology and requires careful development and design.

NSO has responsibility for leading the ATST development and for conducting ATST operations to ensure access by the entire solar physics community. Partnerships with US universities, industry, HAO and other government laboratories, and international groups are being sought and will play a key role in developing the ATST. Several of the universities that have expressed interest include the University of Hawaii, Michigan State, Montana State, NJIT, Caltech, Rochester, Chicago, Colorado, Cal State Northridge, UCLA, UC-San Diego, Stanford, Harvard, and Princeton. Other government laboratories and industry include HAO, NASA/Marshall Space Flight Center, the Naval Research Laboratory, the AFOSR/AFRL, and Lockheed Palo Alto Research Laboratories. International groups include Germany, Sweden, Japan, Switzerland, Spain, and Italy. NSO will coordinate these interests and write a design and development phase proposal for submission to NSF in the fall of 2000.

In addition to the incremental funding sought through a design and development phase proposal, NSO has made substantial investments in the ATST. NSO programs include preliminary concept studies, site surveys, demonstration of solar adaptive optics, and development of infrared technologies. NSO will continue its investment in the ATST from its base funding as shown in Table 1 on page 21 and broken down in Table B.1 below. We expect that a substantial part of the ATST development effort will occur through external contracts to university and private sector groups and within other government labs and through international partners. The tables below show estimates for the incremental funding needed to implement the design and development phase and estimates for the construction phase. These estimates will be revised as the design and development phase proposal is developed. End products of the design and development phase will include a completed design, including working drawings for manufacture and construction, a work breakdown structure and management plan for building the ATST, a plan for operation of the ATST, and a thoroughly costed construction phase proposal. Key milestones in the design and development phase will include a conceptual design review, a preliminary design review, an assessment of the effectiveness of high-order adaptive optics for a large-aperture solar telescope, a critical design review, and submission of the construction phase proposal. The NSF will have the opportunity to review the project at each milestone to make funding decisions. The costs shown in the tables are preliminary and will be finalized before submitting the design and development phase proposal.

ATST Funding Profile

B.1

ATST Development from NSO Base Program (Includes contribution from SOLIS Wedge) (Does not include scientific staff contributions)

(Dollars in thousands)	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
ATST Technology Issues										
Adaptive Optics										
Low-Order AO	305									
High-Order AO										
MRI Proposal		700	600	500						
NSO Contribution to MRI		296	205	370						
ATST Technology Development				71	837	1,234	1,271	1,309	1,348	1,389
Site Testing	52	580	155	159	164					
Focal Plane Instrumentation										
Defraction Limited Polarimeter			145	175						
IR Technology		190	200	200	200					
NSO In-House Contribution	\$357	\$1,766	\$1,305	\$1,475	\$1,201	\$1,234	\$1,271	\$1,309	\$1,348	\$1,389

B.2 ATST Development Proposal (to NSF Sept. 2000)

	Conc	ept	Design	& Develop	pment		Constructi	on & Com	nissioning	
(Dollars in thousands)	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09
Project Management		150	150	150	150					
Site Testing			150	150	150					
Design										
Mirror Technology		200	200	200						
Thermal Control		100	100	200	100					
Optical Design		150	500	600	650					
Mechanical Design		100	450	650	700					
Telescope Control		100	200	200	300					
Procurement and Construction						3000	10000	13000	12000	2000
Instrumentation										
IR Technology		100	100	100	100	300	300	300		
AO System		300	100	100	100	800	800	800		
Focal Plane Instrumentation		300	200	200	400	800	2500	2500	1500	1500
Cost		\$1,500	\$2,150	\$2,550	\$2,650	\$4,900	\$13,600	\$16,600	\$13,500	\$3,500
Cummulative Cost		\$1,500	\$3,650	\$6,200	\$8,850	\$13,750	\$27,350	\$43,950	\$57,450	\$60,950

APPENDIX A: MILESTONES FY 2001

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:

- Form ATST management structure
- Develop ATST national and international partnerships
- Develop and submit a proposal for the design and development phase
- Begin ATST trade studies in thermal control, mirror technology, telescope control, optical configuration, dust mitigation and scattered light control
- Complete and field S-DIMM for site testing

Solar Adaptive Optics

- Improve performance (e.g., bandwidth) of 20 Zernicke AO system
- Implement 20 Z system at the Dunn Solar Telescope (DST) as shared-risk user system
- Adapt and/or upgrade post-focus instrumentation for use with AO
- Schedule AO science runs at DST
- Begin design and construction of high order (~80 Z) AO system

SOLIS

- Complete VSM software control system and complete testing at GONG site
- Complete program of cross calibration
- Move SOLIS to Kitt Peak
- Start initial operations
- Fix initial startup problems
- Submit proposal for SOLIS network
- Complete work on OCS Phase 2
- Complete work on DHS Phase 2

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 deploying the high resolution $(1K \times 1K)$ cameras; the project that has been defined as GONG+. The Precision Spectrophotometric Telescopes measure changes in the solar irradiance over the surface of the Sun.

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

RISE/PSPT

- Operate RISE/PSPT station at NSO/SP
- Form partnership with HAO and Hawaii for PSPT maintenance and data processing

Solar Infrared Program

- Take delivery of 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

Spectral Hole Burning Device (SHBD)

- Acquire and install all necessary equipment for a chlorin-in-PVB SHBD
- Record iodine spectrum with an accuracy of better than 1%
- Develop theory and experimental methods for accurate calibration methods
- Record hyperspectral images of the Sun with a signal-to-noise ratio of >500
- Prepare a comprehensive list of possible dyemolecules and plastic films
- Produce high-quality chlorin-in-PVB films on glass substrates
- Perform absolute wavelength measurements in the lab to at least 1 part in 10^8
- Perform initial laboratory experiments to record linear polarization

FTS Imager

• Conduct performance comparison studies of a MCT array detector to a single-element detector

APPENDIX B: STATUS OF FY 2000 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2000 Program Plan. (FY 2000 milestones appear in italics below.)

Advanced Technology Solar Telescope (ATST)

Complete Phase A study document. Prepare proposal for ATST technology studies.

NSO produced a science brochure describing the scientific goals of the ATST. These goals were briefed to NSF and NASA, resulting in strong support from both agencies. A white paper/proposal was prepared, outlining the entire ATST project; this document was used by NSF/Astronomy to put the ATST into the queue for their Major Research Equipment (MRE) funds, possibly beginning in 2005. It also resulted in a request from NSF for a concept and design phase proposal to be submitted at the start of FY 2001.

Construct Solar Dual Image Motion Monitor (S-DIMM) for optical site testing.

The S-DIMM design was modified after joint experiments were conducted with the Chinese at Fuixsan Lake, China. The modified S-DIMM prototype will be completed in September, 2000 and calibration at the Dunn Solar Telescope will commence.

Explore national and international partnership(s).

Discussions were held with several US universities, HAO, and with the Kiepenheuer Institute in Germany. A joint adaptive optics proposal with NJIT, AFRL and the Kiepenheuer was submitted to NSO/MRI funding.

Present ATST to NAS/NRC decade astronomy study.

The ATST was the highest ranked new ground-based facility in the moderate funding category and was ranked second overall in the ground-based category. (Development of new focal plane instrumenation of private observatories was ranked first in the moderate category.)

SOLIS

Complete mount mechanical and electronics procurement and fabrication.

The mount was installed at the GONG prototype site a few km north of the Tucson office. It is being readied for powered operation and testing with dummy instrument loads.

Complete VSM optics procurement and fabrication.

All of the VSM optics are either in fabrication or already received. One Littrow lens element shattered in the vendor's shop and is being redone.

Begin VSM mechanical and electronics procurement and fabrication.

Most of these items either have been constructed, or are under construction. A significant delay in the VSM data acquisition system (DAS) developed when the responsible electronics engineer resigned. A commercial solution was found and work is back on track.

Complete acceptance of PixelVision cameras.

A major delay in constructing cameras has developed at PixelVision. The custom CCDs are reported to be successful but the support electronics and packaging issues have proven to be more difficult than the vendor anticipated. The cameras are not expected before March 2001, a year late. Efforts to accelerate this date are in progress and alternate plans for partial initial operational capability have been developed.

Begin cross-calibration of ISS instrument.

Delivery of the ISS instrument by the major vendors was late. The ISS is now able to take high quality spectra and a program of cross calibration with existing equipment is expected to begin before the end of FY 2000.

Complete FDP mechanical and electrical designs.

These tasks are under way and will be completed before the end of FY 2000. This instrument has the lowest scientific priority and waited for higher priority tasks to be completed.

Complete FDP optics procurement and fabrication.

All of the commercial off-the-shelf optics required for the FDP have been received. Custom optics are being procured at this time.

Begin FDP mechanical and electrical procurement and fabrication.

A considerable amount of work has been done on adapting a shutter design kindly provided by Lockheed-Martin for use in the FDP. All of the hardware and electronic components for this device have been acquired and are being tested. Most of the remaining mechanical and electronic components are commercial off-the-shelf items.

Complete MCS software development.

The Mount Control System software is undergoing testing using small motors and encoders prior to installation on the real mounting. Further development of the MCS software will be completed on site.

Complete ICS software development.

The Instrument Control System software has been developed with emphasis on running the ISS as the first instrument. This task is largely completed; the detector controller is the only remaining component to be finished. Further instrument software work will be done on the actual instruments.

Complete OCS software Phase 1 development.

The Observing Control System software is divided into two phases. The first phase will provide semiautomatic scheduling and control of SOLIS system while the second phase will make this function autonomous. Phase-1 work is nearly completed, the OCS to instrument interface still needs to be finished and tested. Work on phase-1 will be done before the start of FY 2001.

Complete DHS software Phase 1 development.

The Data Handling System software consists of two major elements. One element transfers data to various processes and hardware devices rapidly and the second element is various algorithms that process the data into scientifically useful data products. The VSM generates the most challenging data

sets and development work, consisting of simulations of real observations, and their processing is well advanced. This work will extend into early FY 2001.

GONG

Operate and maintain the network and coordinate activities with host sites. Develop additional software for analysis of instrument functions. Reduce network data and deliver to the community. Continue to test and refine the GONG+ prototype system. Develop data acquisition software for high-resolution camera. Develop analysis pipeline for high-resolution data.

The GONG stations continue to operate reliably, with the scientific duty cycle frequently exceeding 90% and the equipment downtime being less than 2%. Forty-six months of GONG data (four years of nearly continuous images from the six-site network) have been processed and made available to the community.

Delay in the delivery of the data acquisition system (DAS) prototype, and subsequently the lack of extended run-time of the prototype system has caused the GONG+ deployment schedule to slip well into CY 2000. The system continues to be tested, evaluated, and optimized. The DMAC group is currently processing full-resolution images from the GONG+ prototype instrument, addressing the topics of instrument characterization, calibration, geometry, cadence, continuous magnetograms, and data compression. We anticipate that the GONG+ instruments will be operational by the end of CY 2000.

Solar Adaptive Optics

Improve performance (e.g., bandwidth) of 20 Zernicke AO system. Implement 20 Z system at the Dunn Solar Telescope (DST) as shared-risk user system. Adapt and/or upgrade post-focus instrumentation for use with AO. Schedule AO science runs at DST. Begin design and construction of high order (~80 Z) AO system.

The solar adaptive optics program at NSO/Sac Peak is on schedule for achieving all major milestones set for FY 2000. A quantitative system performance analysis was performed. Strehl ratios were estimated using a phase diversity and the Shack-Hartmann WFS outputs.

Based on this analysis the system performance has been improved, e.g., the bandwidth of the system was increased by about a factor of 4 and improved control algorithms were implemented. Several software improvements implemented that resulted in a more user friendly system. During the campaign on Tenerife, the system has proven to be surprisingly robust. An improved optical AO setup is currently installed at the DST and automated calibration procedures will be implemented by the end of FY 2000. A preliminary design for the high order AO has been completed. A joint proposal between NJIT/BBSO, KIS/Freiburg and NSO for the development of three AO systems was submitted to the NSF-MRI program and has been funded.

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 Telescope. Submit joint proposal with HAO and Hawaii for large format IR camera based on HgCd arrays for the Dunn Solar Telescope.

Bids on the Request for Proposal have been received; negotiations aimed at cost reduction are underway. Based on the schedules submitted by the vendors, delivery is expected early in FY 2002.

The collaboration with HAO and Hawaii did not materialize.

APPENDIX C: NSO FY 2001 BUDGET SUMMARY

(Dollars in Thousands)	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	TOTAL BUDGET
Director	236						236
Scientific Staff		529	717	160			1,406
Scientific Support/Computing		313	163	657			1,133
Instrument Development/Maint.		264	76	300	486		1,126
Telescope Operations		160	127	930		50	1,267
Facilities		611					611
Administrative Services		206		154			360
Visitor Center/Public Outreach		55					55
Construction						430	430
Site Testing					580		580
NOAO Support			1,058				1,058
AURA Management Fee	154						154
Base Program Total	\$390	\$2,138	\$2,141	\$2,201	\$1,066	\$480	\$8,416
Programmed Indirects	(18)	(87)					(105)
Housing Revenue		(59)					(59)
Meal Revenue		(16)					(16)
Air Force Support		(432)					(432)
NASA Support			(32)				(32)
Visitor Center Revenue		(50)					(50)
BASE PROGRAM – NSF	\$372	\$1,494	\$2,109	\$2,201	\$1,066	\$480	\$7,722

Karatholuvu R. Balasubramaniam, Associate Scientist

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

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

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 Advanced Stokes Polarimeter. Bala is also working on the role of magnetic field in the heating process in solar active regions. He is collaborating with L. A. Smaldone (University of Naples) on understanding upper atmosphere heating using SiI 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.

Bala will continue to work on the the goal of understanding filament eruptions leading to mass ejections, with accompanied solar flares. This program involves studying full-disk H α filament eruptions observed at Sac Peak, with a cadence of one minute. He will use the existing data, spread over several solar cycles to seek and analyze the physical characteristics leading to mass ejections. He will also work on the large-scale flow patterns of the Sun, seeking velocity driver signatures leading to solar mass ejections. When SOLIS becomes available, he will incorporate its data in these studies. 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 actively involved in the Research Experience for Undergraduates (REU) Program and the Summer Research Assistant (SRA) Program at NSO/Sac Peak. He will chair the REU and SRA programs for NSO. He is chair of the NSO/SP Telescope Allocation Committee and advises non-NSO users on observing at NSO/SP facilities. He is also a prime point-of-contact for public outreach questions on astronomy and also conducts public observatory tours from time to time. Bala participates in the planning efforts for theAdvanced Technology Solar Telescope. He is investigating telescope thermal control and other technical issues related to the ATST. Bala supervises the operations of the SP Library. He provides advice on polarimetry issues to the USAF/AFRL group developing the ISOON telescopes.

Jacques M. Beckers, Astronomer

Areas of Interest

Solar Atmosphere, Astronomical Instrumentation, Atmospheric Seeing, Multu-Conjugate Adaptive Optics, Large Telescopes

Future Research Plans

Beckers will continue with his high angular resolution observations of sunspots and chromospheric structure, as well as experiments in atmospheric tomography.

<u>Service</u>

Beckers will complete the construction of the Advanced Technology Solar Telescope site test telescopes and assist in their deployment.

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.

Richard B. Dunn, Astronomer Emeritus

<u>Areas of Interest</u> High Resolution Imaging, Instrumentation

Future Research Plans

Dunn plans to continue his work on improving the quality of resolution at the Dunn Solar Telescope. He will also continue to consult on the upgrade to the Solar Observing Optical Network (SOON).

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 the numerous 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 FY00. 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.

Future Research Plans

Giampapa intends to continue working on the M67 project. As a member of SONG (Stellar Oscillations Network Group), Giampapa will be participating in an HST experiment to detect p-mode oscillations in solar-type stars (J. Valenti, PI). The data have just been obtained and are undergoing reduction. In collaboration with T. Fleming and J. Liebert (Steward Observatory, U. of Arizona), Giampapa will be submitting proposals for the second round of Chandra Guest Investigator observations. Their requests will emphasize X-ray observations of brown dwarfs and low-mass stars near the critical mass limit for hydrogen core burning. Data for approved Cycle 1 observations with Chandra will be obtained in early FY01. In collaboration with Dr. Eric Craine (Western Research & GNAT, Inc.), Giampapa and an REU student will be investigating 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 low-level, 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. He also serves in a scientific advisory role for the NOAO Next Generation Optical Spectrograph (NGOS) project. 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 elected member of the Solar Physics Division (SPD) Committee and an editorial board for New Astronomy Reviews.

John W. Harvey, Astronomer

Areas of Interest

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results

Demands of the SOLIS and GONG upgrade projects have precluded doing significant scientific research during FY 2000. Several projects are in a state of suspension. This unfortunate situation is unique in Harvey's 38-year career of producing and publishing research results.

Future Research Plans

During FY 2001, J. Harvey will concentrate on the SOLIS and GONG upgrade projects 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 actively comparing KPVT integrated full-disk synoptic signals with recent solar wind velocity results that report evidence for active solar longitudes. As a byproduct of this work, he has developed a method to use signal phase information to measure the coherency of a signal, which may potentially be helpful for helioseismic analysis of very low frequency mode candidates. In his thesis work, Henney analyzed the observed GOLF signal and a selection of spatially masked SOI-MDI full-disk signals for a 759 day period. Using cross-amplitude and averaged power spectra, an unique list of low degree modes was presented, along with three new low frequency acoustic mode candidates. Henney continues to collaborate with L. Bertello, F. Varadi and R. Ulrich of UCLA in the analysis of the GOLF and MDI full-disk velocity signals.

<u>Service</u>

As Data Scientist for the SOLIS project, Henney has worked on the development of the Data Handling System. He has created software to handle geometric corrections for the VSM. Additionally, he has begun to generate the data reduction algorithms needed to calibrate the raw VSM spectral images. Besides, he co-maintains the current KPVT synoptic data pipeline, and has assisted with KPVT observations. Henney will continue to modify and update the KPVT synoptic data reduction pipeline to process SOLIS-VSM data. Furthermore, he has begun developing data reduction algorithms needed to create near "real-time" SOLIS-VSM data products.

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.

Robert F. Howard, Astronomer Emeritus

Areas of Interest

Observational Study of Surface Active-Region and Sunspot Orientations and Velocities as Diagnostics of Sub-Surface Conditions Related to the Dynamo Process in the Sun

Recent Research Results

Work in collaboration with K. R. Sivaraman and S. S. Gupta of the Indian Institute of Astrophysics in Bangalore, India, using the combined Kodaikanal (India) and Mount Wilson data sets has confirmed the active region tilt angle vs tilt angle change relationship found earlier by Howard using the Mount Wilson data set alone. If the sunspot groups are separated into data subsets with tilt angles greater than and less than the average value, they show tilt angle varations that vary systematically with the growth or decay rates of the groups. This result emphasizes the fact that younger (growing) regions rotate their magnetic axes more rapidly than do older regions. Tilt angle changes and polarity separation changes show a clear relationship, which has the correct direction and magnitude predicted by the action of the Coriolis force on the rising magnetic flux tubes. This strongly suggests that the Coriolis force plays a major role in the initial orientation of the magnetic axes of regions.

Future Research Plans

Howard will continue studies of surface characteristics of solar active regions as diagnostics of subsurface flux tube dynamics. This work promises to shed light on the dynamo process that is believed to operate near the base of the solar convection zone. These studies will center on analyses of the inclinations (to the vertical) of the magnetic fields of active regions and will be carried out in part in collaboration with K. R. Sivaraman and S. S. Gupta (Indian Institute of Astrophysics, Bangalore).

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. A paper on this subject has recently been published in the Astrophysical Journal. The work is now being extended (with S. Basu and H. M. Antia), using

inversion techniques to investigate the distribution of sound-speed changes related to the solar cycle. 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 the same 3-month period in an attempt to clarify the systematics involved in the analysis methods. This work was presented at the GONG'99 workshop and is currently being prepared for publication. The same group went on to study changes in the solar rotation as the solar cycle progresses. This work has resulted in recent publications in Astrophysical Journal Letters and Science. The Science article was featured in press releases from NOAO, NSF, NASA and ESA, and attracted some media attention. 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. Howe served on the Local Organizing Commitee for the GONG'99 workshop. Howe will supervise a summer student in this year's programme.

Stephen L. Keil, Director, NSO

Areas of Interest

Solar Activity and Variability, Astronomical Instrumentation, Solar Convection and Magnetism

Recent Research Results

Keil, in collaboration with Drs. L. Milano and K. S. Balasubramaniam and REU students Adam Bayliss (University of Montana), Jeremy Jones (Lehigh Univ.), Robert Gutermuth (Alfred University), and Michael Gericke (University of Arkansas) have continued their program to carefully map flow fields in solar active regions. The observations span the solar atmosphere from the deep photosphere to the low chromosphere. The observations reveal that the amount of vorticity in surface flows in the solar photosphere and in proper motions in the chromosphere increases significantly before activity events such as prominence eruptions and flares. Working with REU student Scott Catanzariti (Indiana State University), Keil has investigated 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.

Future Research Plans

Keil is leading efforts to define an advanced high-resolution solar telescope. He will continue working with 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 2001.

<u>Service</u>

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

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

Keller, in collaboration with Rick Paxman, John Seldin, Dave Carrara, and Kurt Gleichman of ERIM International, and Thomas Rimmele, has obtained the highest resolution magnetogram movies ever obtained. 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 his time during the next year, Keller 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 facility and occasionally at the Sacramento Peak facilities. He is the lead scientist for the real-time software and hardware efforts for SOLIS and leads the Vector-Spectromagnetograph effort. He is a member of the local and NSO-wide Project Review Committees and reviews observing proposals for other national and international facilities. As telescope scientist for the ATST, Keller is heavily engaged in the design and development activities for the project.

Rudolf W. Komm, Junior Scientist

Areas of Interest

Helioseismology, Dynamics of the Solar Convection Zone, Solar Activity Cycle, Rotation and Meridional Motion of Sunspots

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. Komm will continue to study advanced time-series analysis techniques in order to evaluate their usefulness for helioseismology. Komm will continue to study the solar rotation and meridional motion of solar surface tracers such as sunspots in collaboration with J. Javaraiah (Bangalore, India).

<u>Service</u>

Komm continues as a participant in Project ASTRO.

John W. Leibacher, Astronomer

Areas of Interest

Helioseismology, Atmospheric Dynamics

Recent Research Results

The first 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 and the detection of gravity modes 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 Goddard Space Flight Center's Space Sciences Visiting Committee and the AAS Solar Physics Division's Hale Prize Committee.

William C. Livingston, Astronomer Emeritus

Areas of Interest

Solar Magnetic Fields, Solar Rotation, Solar Spectrum Variability with Time (Sun-as-a-Star), IR Spectrum Atlases

Recent Research Results

Making use of the McMath-Pierce all reflective system, Livingston has made exploratory observations of prominences in Pfund β (4.6 μ), Bracket α (4.0 μ), Balmer α (0.65 μ), Balmer β (0.48 μ), and Ca K (0.39 μ). It is found that while the visible lines are usually optically thick, resulting in sampling of only the prominence skin, the IR lines are optically thin. This means the IR lines penetrate the complete prominence body. Cao Wenda (Yunnan Observatory) is currently modeling the results.

Livingston continues his long-term monitoring of the Sun's irradiance spectrum. In collaboration with O.R. White (HAO/NCAR), they have a continuous record since 1974 of the behavior of chromospheric

Calcium H and K, Helium 10830, H α 6562, Calcium 8542, photospheric Carbon 5380, Beryllium 3131, and various Iron lines. Some long-term secular trends have been discovered, indicating subtle alterations in the solar output. The ISS (solar high dispersion spectrometer) of SOLIS will eventually take up this program on a daily basis. The present aim is to overlap ISS and the present 13.5-m spectrograph data streams so they can be tied together.

Livingston also makes two to three observations per year with the 1-m FTS. This archive goes back to 1980 and is an attempt to track spectrum line asymmetry arising from the average convective motions of the 3 million plus granules on the disk. It could be that the weak fields mentioned above suppress in a variable way granular convection, possibly another link in the Sun-Climate relation.

Future Research Plans

Livingston plans to continue with the above programs, especially the spectrum monitoring.

<u>Service</u>

Livingston acts as the resource person for phone queries and other requests for solar information. He has helped Turkish Astronomers prepare for the August 11, 1999 total eclipse, including a post-eclipse international meeting on eclipses.

Alexei A. Pevtsov, Associate Astronomer

Areas of Interest

Solar Magnetic Fields, Sunspots, X-ray Corona, Evershed Flow, Helicity, Penumbral Fine Structure, Space Weather, Vector Polarimetry

Recent research results

A. Pevtsov has been studying the coronal X-ray luminosity and photospheric magnetic field in the quiet Sun soft X-ray data from Yohkoh and Kitt Peak daily magnetograms. Between 1991 (active Sun) and 1996 (quiet Sun), the X-ray luminosity at the heliographic center decreases more than a factor of seven, while the magnetic flux decreases by a factor of two. A similar tendency is observed for high latitude samples. Apart from the cycle-related variations, areas of the quiet Sun exhibit significant non-periodic changes in X-ray flux. These variations occur on nine-to-twelve-month intervals and clearly correlate with increase/decrease in sunspot activity. Similar variations are present in the total X-ray irradiance averaged over the solar disk. On the contrary, the magnetic fluxes from the same areas of the quiet Sun show no corresponding variations on this time scale. It was concluded that the X-ray luminosity in the quiet Sun is primarily associated with the strong magnetic fields of active regions, not with weak photospheric fields. A. Pevtsov has also been studying a correlation between orientation of the magnetic field in coronal sigmoidal loops and magnitude of geomagnetic storms associated with eruption of these sigmoids. He found a tendency for sigmoids with particular orientation to produce stronger geostorms. The relative role of other parameters of interplanetry magnetic clouds associated with sigmoid eruptions remains to be analyzed. A. Pevtsov continues to collaborate with several researchers on other projects including the study of magnetic/current helicity, the relationship between coronal and photospheric electric currents, origin of helicity in the quiet Sun and comparison between observed and extrapolated coronal magnetic fields.

Future Research Plans

A. Pevtsov will continue to study the role of photospheric magnetic field in coronal heating using Yohkoh, SoHO/MDI and EIT data. He will also continue his work on studies of the relationship between solar drivers and associated geomagnetic events. He plans to include data from the WIND spacecraft to study the relative role of solar and interplanetary space parameters on magnitude of geomagnetic storms. Other research plans include the study of coronal counterparts of chromospheric filaments and their role in CMEs and search for observational evidence of near-surface (photospheric) dynamo.

<u>Service</u>

A. Pevtsov (in collaboration with D. Longcope) has written two subsections for the science section of the ATST design and development proposal. He has also participated in NSO/Sac Peak TAC meetings and reviewed NSO/SP observational proposals.

Thomas R. Rimmele, Associate Astronomer

Areas of Interest

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

Recent Research Results

Rimmele has recently 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 is involved in the adaptive optics program at NSO. In particular, he is developing techniques for wavefront sensing for extended objects. Working with the Air Force Research Laboratory (AFRL), he is developing the active optics system at the Dunn Solar Telescope at Sac Peak which corrects optical aberrations that vary on slow time scales and also serves as a test bed for further development of adaptive optics. He is planning to build a low-order (~20 modes) adaptive optics system within the next two years as an intermediate step toward a full-up adaptive optics system. The low-order AO system will provide diffraction limited imaging during reasonable seeing conditions. 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 narrow-band filter capabilities for the DST using Fabry-Perots and participates in an ongoing effort to upgrade CCD detectors at NSO/SP. Rimmele serves as Chair of the Sac Peak site Project Review Committee (PRC) and is Project Scientist for the ATST Project.

Michael Sigwarth, Postdoctoral Research Associate

Areas of Interest:

Solar Magnetic Fields, Flux Tube Dynamics, Formation of Active Regions, 2D Spectroscopy, High-Resolution Observation

Recent Research Results

Sigwarth has recently published results on the formation of extreme asymmetric Stokes-V profiles measured with the NSO/HAO Advanced Stokes Polarimeter (ASP) in network and plage fields. Based

on simple atmospheric configurations with separate layers of flow and magnetic fields, such profiles can be reproduced. In order to clarify the actual formation process of such unusual V-profiles, spectropolarimetric observations with higher spatial resolution are necessary. During the last year, Sigwarth reinstalled and new setup of the existing Dual Fabry-Perot spectrometer at the DST. First results obtained in combination with the low-order AO system early this year demonstrate the potential of diffraction-limited 2D spectroscopy with these systems. The obtained data address questions on the origin and formation of active regions.

Future Research Plans

There are plans to build a new Stokes polarimeter, in collaboration with HAO, in order to achieve diffraction-limited, high-precision spectropolarimetric observations in combination with a high-order AO system. Sigwarth is leading the NSO efforts in this collaboration, with plans to upgrade the existing ASP within this fiscal year. A new camera and demodulating and calibration system will be installed which will make this polarimeter a potential post-focus instrument for a large-aperture solar telescope in combination with a high-order AO system.

Sigwarth is planning to use the upgraded ASP during calendar year 2000 to address questions of flux tube formation and dynamics as well as Stokes-V formation. In collaboration with the Astro-physikalisches Institut Postdam (AIP), Germany. He plans to investigate oscillations in active regions in photospheric and chromospheric layers with the ASP, TRACE and the VTT/Canary Islands and to compare the results with theoretical models developed at the AIP (sunspot filter theory).

<u>Service</u>

Sigwarth is currently organizing the 20th Sac Peak Summer 2000 Workshop on "Advanced Solar Polarimetry – Theory, Observation, and Instrumentation." He assists on observations with the HAO/NSO Advanced Stokes Polarimeter and with handling, calibrating and analyzing the data. He is also developing software for handling and analyzing 2D spectroscopic data. Sigwarth has been organizing the NSO/SP colloquium series since spring 2000.

Raymond Smartt, Astronomer Emeritus

Areas of Interest

Coronal and Prominence Dynamics; Coronagraphic Instrumentation and Narrow-Band Tunable Filters

Recent Research Results

Flare-Associated Coronal Loop Systems. The morphological details of four events have been measured and analyzed and corresponding parameters derived. The combined results appear to be inconsistent with the commonly accepted model for the development of such coronal loop systems. Smartt is working with external colleagues on several problems in coronal physics.

Future Research Plans

Localized deficits in Coronal Emission. Earlier work attempted to interpret observed deficits in visibleline coronal emission as due to a specific absorption mechanism. This model was shown to be consistent with expected densities, but nevertheless had consequences that appeared to be inconsistent with other observational evidence. Ongoing work is directed towards resolving this problem. Coronal Loop Interactions. The phenomenon of the observed continued localized cooling of the plasma at the site of a coronal loop interaction (CLI), over tens of minutes following an event, to temperatures far below that of the ambient corona, will be studied further.

<u>Service</u>

Smartt is principally responsible for the development of the science exhibits in the NSO/SP Visitor Center, which continues as a major effort covering a wide variety of displays. With an external Co-I, he

is working actively on details of a new design concept for an off-axis reflecting coronagraph system. Smartt is a Co-I on the LASCO instrument of SoHO, and on other space instrumentation proposals.

Clifford Toner, Assistant Scientist

Areas of Interest

Global and Local Helioseismology, Image Restoration, Data Analysis Techniques

Recent Research Results

Toner has been updating and improving the analysis of GONG drift-scan data in order to obtain better estimates for the absolute orientation of GONG images. The Mercury transit on Nov. 15, 1999 provided a valuable opportunity to determine the accuracy of the updated routines. The transit was observed by three of the GONG instruments (Moana Loa, Big Bear, and Tucson (with a new high resolution camera)). Toner has analyzed these data to determine the absolute orientation of GONG images and has compared the results to those obtained from the analysis of drift-scans. He found that the drift-scan results agreed with the Mercury transit results to within ~0.01 degrees for the Tucson data (i.e., high-resolution camera) and to within ~0.04 degrees for the other sites (low-resolution camera).

Toner has continued his search for solar g-modes using annulus data extracted from full-disk intensity images obtained by the MDI instrument on board the SoHO spacecraft. Unfortunately, the results have thus far proven negative.

Future Research Plans

Toner will devote most of his time to the support of the GONG+ upgrade. This will involve developing new data reduction algorithms and the design and implementation of codes for local helioseismology.

<u>Service</u>

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

Han Uitenbroek, Assistant Astronomer

Areas of Interest

Radiative Transfer Modeling, 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 McMath-Pierce telescope at Kitt Peak, reveal the important role the 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, showing that the inverted contrast is due to convection overshoot into the stable layer overlying, 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 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.

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.

APPENDIX E: NSO MANAGEMENT

Stephen L. Keil	Director
Mark S. Giampapa	Deputy Director
John Leibacher	Project Director, GONG
Pat Eliason	Manager, GONG Project
Jeremy Wagner	Manager, SOLIS Project
Rex Hunter	Administrative Manager, Sacramento Peak
Thomas Rimmele	ATST Project Scientist
Christoph Keller	ATST Telescope Scientist

NOAO Managers Supporting the NSO Program

Larry Daggert	Manager, Engineering and Technical Services (ETS)
Steve Grandi	Manager, Center Computer Services (CCS)
Larry Klose	Manager, Central Administrative Services (CAS)
Sandra Abbey	Human Resources Manager
James Tracy	Controller
Glen Blevins	Financial Manager
John Dunlop	Facilities Manager
Suzanne Jacoby	Manager, Educational Outreach
Jane Price	Manager, Public Outreach

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 2001 facilities maintenance projects at each site are described below.

NSO – Sac Peak

The FY 2001 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. The general funds will be used for repainting a variety of telescope and commercial buildings, continue upgrading our lighting and installing cathodic protection on the overhead 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 that will be funded through year-end funds if they are available. This item was carried forward from FY 2000 because funds were not available during that FY. Year-end funds were used to purchase a staff vehicle, which appeared on last year's summary.

Project (Dollars in Thousands)	Est. Cost
Painting – Commercial buildings	\$25
ADA compliance	25
Underground utility replacement	35
Housing Upgrades	20
Total	\$105

NSO Sac Peak Facilities Program FY 2001

• Commercial/Telescope Painting

A variety of commercial and telescope buildings require painting. These include the Main Lab, Hilltop Telescope and the Evans Solar Facility. This will be a multi-year project.

• Lighting Upgrades

Commercial lighting around the Peak is 1960's vintage and upgrades would reduce utility costs and improve the working environment. The Main Lab and shop areas are highest priority for replacement. This is also a multi-year project.

• 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.

• Cloudcroft Facility

NASA recently 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.

NSO – 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.

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

NSO Kitt Peak Facilities Program FY 2001

• 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 1999 Telescope Usage Statistics

A. *Number of Observing Runs Using NSO Facilities:

Quarter	FY99
1 (Oct – Dec)	43
2 (Jan – Mar)	41
3 (Apr - Jun)	43
4 (Jul – Sept)	47
TOTAL	174

*includes NOAO/NSO staff projects

- B. Total number of unique science projects: 86
- C. Users by Category:

		NOAO/NSO STAFF		
	U.S.	Foreign	Total	
PhDs	69	17	86	20
Graduate Students	4	1	5	-
Other (technicians,	6	1	7	10
research assistants, etc.)				
TOTAL	79	19	98	30

D. Institutions Represented by Visiting Users:

	U.S.	Foreign	Total
Academic	19	7	26
Non-Academic	11	6	17
Total Academic & Non-Academic	30	13	43

E. Number of Visitors by Nationality:

Australia	1	Japan	1
Canada	4	Mexico	1
Germany	1	China	1
India	3	Spain	1
Italy	3	Switzerland	1

APPENDIX H: NSO ORGANIZATIONAL CHART

NATIONAL SOLAR OBSERVATORY



[1] See H-1, GONG project staff

- [2] See H-2, SOLIS project staff
- [3] ETS staff assigned to ID projects
- [4] NSF/Chemistry project funded personnel[5] NASA project funded personnel
- [5] NASA project funded personnel
 [6] .50 NSF/.50 ONR project funded personnel
- [6] .50 NSF/.50 ONR project funded personne[7] Funded by Visitor Center revenues



SYNOPTIC OPTICAL LONG-TERM INVESTIGATIONS OF THE SUN SOLIS PROJECT

NSO GLOBAL OSCILLATION NETWORK GROUP



APPENDIX I: ACRONYM GLOSSARY

AASC	Astronomy and Astrophysics Survey Committee
AFOSR/AFRL	Air Force Office of Scientific Research/Air Force Research Laboratory
AO	Adaptive Optics
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
CY	Calendar Year
DAS	Data Acquisition System
DHS	Data Handling System
DLT	Digital Linear Tape
DMAC	Data Management and Analysis Center
DST	Dunn Solar Telescope
DVD	Digital Video Disk
ESF	Evans Solar Facility
ETH-Zürich	Eidgenössische Technische Hochschule-Zürich
FDP	Full Disk Patrol
FP	Fabry-Perot
FTS	Fourier Transform Spectrometer
FWHM	Full-Width-at-Half-Maximum
FY	Fiscal Year
GB	Giga Bytes
GONG	Global Oscillation Network Group
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
ICS	Instrument Control System
ISS	Integrated Sunlight Spectrometer
KIS	Kiepenheuer Institute for Solar Physics
KPNO	Kitt Peak National Observatory
KPVT	Kitt Peak Vacuum Telescope
LAN	Local Area Network
MCS	Mount Control System
MCT	Mercury-Cadmium-Teluride
MHD	Magneto Hydrodynamic
MRE	Major Research Equipment
MRI	Major Research Instrumentation

APPENDIX I: ACRONYM GLOSSARY

NAS National Academy of Sciences	
NASA National Aeronautics and Space Administration	
NICMASS Near Infrared Camera MASSachusetts	
NJIT New Jersey Institute of Technology	
NOAA National Oceanic and Atmospheric Administration	
NOAO National Optical Astronomy Observatory	
NOAO/ETS National Optical Astronomy Observatory/Engineering and Technical Se	rvices
NRC National Research Council	
NSDO National Solar Digital Observatory	
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	
NVO National Virtual Observatory	
OCS Observing Control System	
PSPT Precision Solar Photometric Telescope	
PVB Polyvinyl Butyl	
RA Right Ascension	
RAIDs Redundant Array of Independent Disks	
RDBMS Relational Data Base Management System	
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	
SHBD Spectral Hole Burning Device	
SoHO Solar and Heliospheric Observatory	
SOLIS Synoptic Optical Long-term Investigations of the Sun	
SSB Space Studies Board	
STEP Summer Teacher Enrichment Program	
STEREO Solar Terrestrial RElational Observatory (2 spacecraft)	
TB Tera Bytes	
TCS Telescope Control System	
TRACE Transition Region and Coronal Explorer	
UV Ultraviolet	
VMG Vector Magnetograph	
VSM Vector Spectromagnetograph	
VSO Virtual Solar Observatory	
VTT Vacuum Tower Telescope	
WFS Wavefront Sensor	
WWW World Wide Web	
Yohkoh "Sunbeam," Satellite project of the Japanese Institute of Space and Astro	onautical Sciences
ZIMPOL Zürich IMaging POLarimeter	