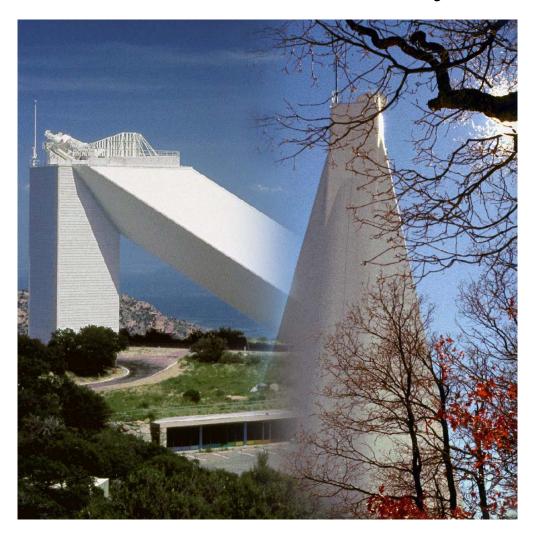


National Solar Observatory



FY 2003 Provisional Program Plan

July 9, 2002





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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I INTRODUCTION

The NSO reached several key milestones in its multi-year program to renew national ground-based solar observing assets. Among these milestones were establishment of the Advanced Technology Solar Telescope (ATST) design effort, fielding of the ATST site survey, completion of the GONG++ upgrade, and implementation of Phase I of the Diffraction-Limited Stokes Polarimeter (DLSP is an upgraded of the Advanced Stokes Polarimeter (ASP)). The major components of the NSO long-range plan include: continuing to lead the development of the 4-m ATST; developing adaptive optics systems that can fully correct large-aperture solar telescopes; completing and operating the instruments comprising the Synoptic Optical Long-term Investigations of the Sun (SOLIS); operating the Global Oscillation Network Group (GONG) in its new high-resolution mode; and an orderly transition to a consolidated NSO structure, which can efficiently operate these instruments and push the frontiers of solar physics. These planned instruments and NSO structure will play key roles in a vigorous US solar physics program. The NSO 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 magnetism and interior dynamo processes
 - Creation and destruction of magnetic field
- Coupling of the solar interior and surface
 - Irradiance variations
 - Build-up of stored magnetic energy which can fuel solar activity
- Coupling of the solar surface and the envelope
 - Coronal heating
 - Flares
 - Coronal mass ejections (CMEs)
 - Space weather and terrestrial effects
- Exploring the unknown
 - Fundamental plasma Magnetic field processes

The NSO encourages broad community involvement in its programs through partnerships to build instruments, develop new facilities and to conduct scientific investigations. Agreements have been established with HAO, the New Jersey Institute of Technology (NJIT)/Big Bear Solar Observatory (BBSO), the University of Hawaii, the University of Chicago, and the University of California San Diego for their efforts in the ATST collaboration. Agreements with other members of the twenty-two institutions that proposed to NSF for the design and development of the ATST are being developed. NJIT/BBSO, the Air Force Research Laboratory (AFRL) and the Kiepenheuer Institute (KIS) in Freiburg are continuing their collaboration with NSO to develop high-order solar adaptive optics (AO). NSO and HAO have begun Phase II in the development of the Diffraction-Limited Stokes Polarimeter, a high-resolution version of the Advanced Stokes Polarimeter that will take full advantage of adaptive optics to measure small-scale solar magnetic fields, and will enable diffraction-limited polarimetry at the Dunn Solar Telescope (DST). NSO will continue to pursue a second and third SOLIS site with the Instituto de Astrofisica de Canarias (IAC) in Spain (which the Spanish would operate in the Canary Islands) and with the Beijing Astronomical Observatory in China. We will continue to work closely with the Air Force, NASA and NOAO to provide

critical synoptic observations that, in addition to producing noteworthy science, also support space and other ground-based observations.

This program plan presents in detail what NSO proposes to accomplish in FY 2003 with its base funding of \$7.97M and with the incremental funding it will receive for ATST design and development.

The NSO program is highly invested in the future need for a healthy US ground-based solar physics program. NSO pioneered solar adaptive optics (AO) and will continue pioneering high-resolution solar physics as instruments line that can fully exploit AO are brought on. AO has given the DST a new role as a diffraction-limited telescope, resulting in a strong (50-100%) over subscription for available time. NSO has also pioneered the use of infrared (IR) technologies in solar physics. The McMath-Pierce Solar Telescope (McMP) is the premier facility for IR studies of the Sun, for high-resolution solar and laboratory spectroscopy from the UV to the thermal IR, and for extremely precise polarimetric measurements.

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

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

The sections that follow describe the NSO plan to renew its facilities and ongoing operations 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.

II 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 NAS/NRC decadal Astronomy and Astrophysics Survey Committee (AASC) report (Decadal Survey) and with the NAS/NRC report on "Ground-Based Solar Research: An Assessment and Strategy for the Future." Both reports place a high priority on the development of a new high-resolution facility for solar physics. They also emphasize the need for the collection of ground-based solar synoptic data and the need for data management on a national scale. NSO's major initiatives, and its instrumentation program, described in this program plan, support the recommendations of these studies.

Figure II-1 is a roadmap that shows how the NSO facilities will evolve over the next several years. During FY 2003, NSO will replace many of its existing synoptic programs with SOLIS. GONG, with its enhanced resolution (GONG+) provided by the 1024^2 cameras, will achieve full operational status in FY 2003 (GONG++). Working closely with the solar community, NSO will continue the concept and development phase for the ATST, including critical technology studies and demonstrations, such as high-order adaptive optics. The ATST will schedule a conceptual design review for the spring of 2003. The ATST plan calls for submitting a manufacturing and construction proposal by FY 2005, with construction starting in 2006.

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

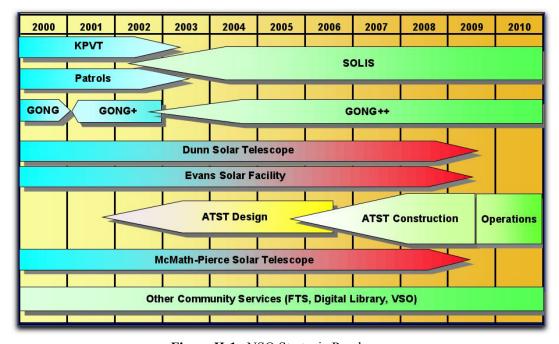


Figure II-1. NSO Strategic Roadmap

1 Initiatives

1.1 Advanced Technology Solar Telescope Project

Working closely with the solar community to develop the Advanced Technology Solar Telescope (ATST) is the new major initiative within NSO.

Development of the ATST will occur in stages. The first phase is for design and development (D&D), which will last approximately four years. During the latter part of 2001, the ATST project began recruiting a design team, entering agreements with partner institutions, and establishing a project office. A science working group was formed and a science requirements document (SRD) for the telescope performance was formulated. Over the next several months, the SRD will be refined and the ATST team will investigate and validate critical technologies needed to design the ATST and produce a preliminary concept for the telescope and instrumentation. These efforts are taking 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, implications of an off-axis design, and the challenges of implementing coronal capabilities. The design phase will culminate with a critical design review and submission of a construction phase proposal. Construction, integratation and commissioning of the telescope will occur during the second phase of the project.

NSO has reprogrammed a substantial part of its in-house effort to support the ATST program. During the past year this included the AO effort, building and fielding site survey instrumentation, and staffing a start-up program office.

1.1.1 Science Working Group and Science Requirements

A Science Working Group, comprising both US and international members, was formed and met twice over the past several months to refine science goals and develop a SRD (see Table I-1). While considerable work still remains in verifying and supporting some of the specific science goals and requirements and developing specifications and derived requirements for the telescope, agreement has been reached on most of the top level science goals.

Understanding and modeling the solar magnetic field is key to understanding most of the major unanswered questions in solar and stellar physics: What heats the outer atmosphere? What is the origin and cause of solar activity such as flares and mass ejections? How does the solar dynamo work and why does the Sun show cyclic variation in activity levels? Observations have established that the photospheric magnetic field is organized in small fibrils or flux tubes. These structures are mostly unresolved by current telescopes. Flux tubes are the most likely channels for storing and transporting energy into the upper atmosphere — where activity is triggered and where the solar UV and X-ray radiation emanate — which in turn affect the Earth's atmosphere. Detailed observations of these fundamental building blocks of stellar magnetic fields are crucial for our understanding not only of the activity and heating of the outer atmospheres of the Sun and late type stars, but also of other astrophysical situations such as the accretion disks of compact objects, or proto-planetary environments.

Thus, resolving and measuring the properties of the magnetic field at its fundamental scale is a primary goal for the ATST. Recent simulations of magneto-convection on the Sun indicate that a resolution of a few tens of kilometers is needed, and the polarimetric observations needed to measure the field properties require a

TABLE I-1. ATST Science Working Group					
Name	Institution				
Thomas R. Rimmele, Chair	NSO				
Thomas Ayres	University of Colorado, CASA				
Thomas E. Berger	Lockheed Martin, Solar & Astrophysics Laboratory				
Fausto Cattaneo	University of Chicago				
G. Allen Gary	NASA Marshall Space Flight Center				
Donald E. Jennings	NASA Goddard Space Flight Center				
Philip G. Judge	High Altitude Observatory				
Stephen L. Keil	NSO				
Christoph U. Keller	NSO				
Jeffrey R. Kuhn	University of Hawaii, Institute for Astronomy				
K. D. Leka	Colorado Research Associates				
Haosheng Lin	University of Hawaii, Institute for Astronomy				
Bruce W. Lites	High Altitude Observatory				
Valentin Martinez-Pillet	Instituto de Astrofisica de Canarias, Spain				
Michael Sigwarth	Kiepenheuer Institut fuer Sonnenphysik, Germany				
Robert F. Stein	Michigan State University				
Jan Stenflo	ETH, Zurich, Switzerland				
Adriaan Van Ballegooijen	Harvard-Smithsonian Center for Astrophysics				
Haimin Wang	New Jersey Institute of Technology/Big Bear Solar Observatory				

large photon flux and accurate knowledge and control of the polarization properties of the telescope. The resolution and flux requirements drive the ATST to at least a 4-meter aperture. To achieve this aperture, the traditional vacuum or gas-filled solar telescope must give way to an open design. The other major goals of measuring the magnetic field in dark features (compared to the surrounding gas), in the upper solar atmosphere and exploiting the infrared, require an excellent control of scattered light and internal heat. Specifications for all of these elements are or will be contained in the SRD.

1.1.2 ATST Project Engineering and Design Progress

This section describes some of the early project efforts including project team formation, initial engineering design, instrumentation MOU's with Co-PIs and other partner work, a cost estimate and a summary of the project's near-term plans.

The ATST project team is drawn from a broad range of resources. These include members of the NSO staff, individuals working from other organizations directly with this group (e.g., AFRL), Co-PI teams primarily looking at instrumentation and operational views, and new hires. Recent additions to the ATST project team include Rob Hubbard as systems engineer and Ron Price as lead opto-mechanical engineer. Table I-2 summarizes the staffing for ATST.

In addition to filling ATST team positions, recent management and systems engineering activities have concentrated on defining the breakdown of the work to be done during the design phase. We have considered possible subcontracting options that may be available during the construction phase and have organized the breakdown of these options with interface requirements and organization in mind. These include an initial Interface Control Document (ICD) organization, creation of a Work Breakdown Structure (WBS) that is consistent with the subsystems, creating an accounting number system that matches both the WBS and ICD organization, and reworking the detailed plans and schedules for the project.

TABLE I-2. ATST and Site Survey Staffing									
	ATST								
Position	Name	Loading	Funding Source						
Project Director	Keil, Steve	0.5	NSO						
Education & Outreach	Dooling, Dave	1	ATST						
Project Scientist	Rimmele, Thomas	0.5	NSO						
Visible Polarimetry Scientist	Keller, Christoph	0.4	NSO						
Near IR Polarimetry Scientist	Penn, Matt	0.3	NSO						
Narrow Band Filter Scientist	Balasubramaniam, K.S.	0.1	NSO						
Thermal IR Scientist	Uitenbroek, Han	0.1	NSO						
Site Survey Scientist	Hill, Frank	0.5	NSO						
Site Survey Science Support	Radick, Richard	0.3	USAF						
Site Survey Manager	Hegwer, Steve	0.3	NSO						
Site Survey Engineer	Briggs, John	1	ATST						
Site Survey Software	Fletcher, Steve	0.3	NSO						
Project Manager	Oschmann, Jim	1	ATST						
Deputy Project Manager	Wagner, Jeremy	1	NSO						
Administrative Assistant	Purcell, Jennifer	1	ATST						
Systems Engineer	Hubbard, Rob	1	ATST						
Optical Engineer	Moretto, Gilberto	0.5	NSO						
Systems Librarian	Kneale, Ruth	1	ATST						
Mechanical Systems	Warner, Mark	1	ATST						
Thermal Systems	Dalrymple, Nathan	0.5	USAF						
Mechanical Designer	Duffek, Jerry	1	NSO						
Opto-mechanical Engineer	Price, Ron	1	ATST						
Software & Control Systems	Goodrich, Bret	1	ATST						
Software Engineer	Wampler, Steve	8.0	ATST						
Civil Engineer	Barr, Jeff	0.2	NOAO						
		16.3	FTE's						

Table I-2. Current ATST project organization. People with NSO or USAF designations ar being contributed to ATST from NSO base funds or USAF funds. Others within the NSO have contributed to the design and organization. There are planned additions to the ATST NSO staff such as Kit Richards for adaptive optics and Lonnie Cole for electronics. The current organizational chart is shown in Appendix H.

Lead engineers have been assigned to each of the major WBS design elements. The current assignments are shown in Table I-3.

Matching budget dollars to each of the major WBS elements for the design phase is currently in process. Design to cost "targets" (based upon recent concept cost estimates) associated with each WBS element for the responsible engineers to work toward have been established. A moderate design case has been selected, without contingency, for the purpose of establishing these targets. It is intended to focus early design efforts towards lower cost solutions.

TABLE I-3.						
Table 1-3. Telescope Assembly Telescope mount M2 assembly M2 assembly Transfer optics Thermal systems Stray and scattered light control Adaptive Optics Instruments Instrument facilities High-level Controls and Software	Mark Warner Mark Warner Ron Price Ron Price Ron Price Nathan Dalrymple (USAF) Rob Hubbard Rob Hubbard Rob Hubbard Jeremy Wagner Bret Goodrich					
Enclosure Support Facilities (includes infrastructure items)	Mark Warner Mark Warner, Jeff Barr (NOAO)					

The current WBS is presented in Appendix H and a chart showing the interface organization (known as an "N²" chart) is available upon request.

Most of the design activities have fallen into the mechanical area and are being led by Mark Warner. In support of this, there has been some iteration on optical designs with input from engineers and science staff including Rimmele, Hegwer, Ren and Oschmann. Warner has also provided support to the site survey effort.

Work has centered on concepts based upon an f/3 primary mirror and an f/2 primary mirror. Considerations for large amounts of lab instrument space have been included in all concepts, but variations that impact cost have been studied. Recent progress has identified some reasonable transfer optical designs that are being worked in conjuntion with the telescope and facility concepts. We have solicited input from the instrument people as to what type of input beam they would prefer.

Figure II-2 shows the concept considered most recently. Beyond the configuration shown, we have looked at several other combinations of other telescope aspects. The images in Figure II-3 illustrate more concepts, including an equatorial mount. We continue to look at these and other options in order to make rough performance, cost, and risk trades during the conceptual stage.

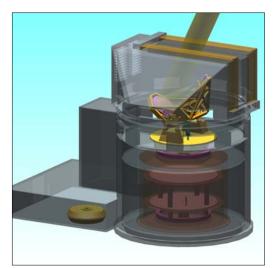


Figure II-2. Most recent concept being considered for the ATST. The concept has a non-co-rotating ventilated dome, an Alt-Az mount configuration, a 4-meter off-axis Gregorian optical design, and a simple-feel optics arrangement to send the beam to a large two-level rotating Coudé labs to allow maximum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

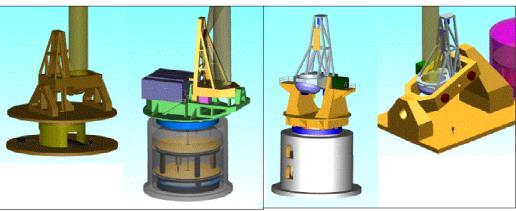


Figure II-3. Additional telescope concepts. The three concepts on the left are various Alt-Az concepts. The first is a compact f/2 optical design, with a short pier and non-rotating Coudé lab. The second is a similar mount design, but with an f/3.75 primary focal ratio, large Nasmyth lab and a two-level rotating Coudé instrument lab. The third from the left puts the elevation axis in a direction normal to the first two; this allows some simplification of enclosure concepts but still has a large primary focal ratio. The last concept is an equatorial mount. There are many more variations that are being considered. This is a representative sample with each having pluses and minuses to trade.

Nathan Dalrymple has been investigating the requirements as well as a few concepts for the prime focus heat stop, which is considered to be one of the key components of the telescope. Success here may indicate how fast a primary we may be able to deal with; this is a cost and feasibility concern. Initial analysis suggests that the heat stop designs consistent with the f/2 primary mirror design are reasonable.

With regard to the primary mirror, informal meetings have been held with 4-5 potential suppliers for their initial thoughts on pursuing fast, off-axis mirrors. More discussions and detailed studies on the issues related to manufacturing this mirror will follow shortly.

N. Dalrymple and Myung Cho (AURA New Inititives Office) have completed initial thermal models for a candidate primary mirror. Cho has completed a first-order finite element model and has built an air temperature profile, solar loading, and a cooling concept to size the magnitude of the thermal control requirements for the primary mirror. His modeling will eventually include thermal temperature differences to the air, thermal gradients throughout the mirror blank, and the resulting distortions to the surface of the mirror. Dalrymple has developed first-order analytic models which compare with the basic finite element model. The first order model will be useful for quick evaluation of various control strategies.

The primary effort in instrumentation has been the establishment of MOU's with most of the Co-PI teams for the initial design work. The following agreements are in place:

High Altitude Observatory (Visible Light Polarimeter Design; Near IR Polarimeter Contributions). **University of Hawaii** (Sky Brightness Monitor and Dust Monitor; Near IR Polarimeter Design (Lead); Site Survey Operations on Haleakala and Mauna Kea).

University of Chicago (Site Survey Project Engineer; Theoretical Support for Science Working Group).

New Jersey Institute of Technology (Site Survey Operations at Big Bear; Tunable IR Filter Design).

University of California, San Diego (Scattered Light Trade Studies).

Initial interactions have begun in a number of areas above. Note that there are some non-instrument areas of involvement, such as site survey support and sky brightness and dust monitors. UCSD has drafted a report documenting their initial scattered light analysis for ATST. Discussions are evolving with respect to requirements and to identify whether there are overlapping areas that the partnership might be able to consolidate and achieve more instrument capability for the money. However, it is too early to foresee what the outcome will be.

Of the partners listed above, we have an agreement with UCSD on the scattered light trade studies and have begun discussions with Lockheed. Other than their letters of commitment, we have not yet put any agreements in place with NASA.

We have, or are working on, several other partner agreements for support both in the telescope and instrument areas:

Lockheed Martin (Broad-band Filter).

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

NASA Goddard SFC (Thermal IR Instrument Design).

One of the recent high priority activities has been to obtain an initial evaluation of the construction costs for some of the concepts being developed. This has been led by M. Warner, with input from many sources such as

other recent telescope projects, including SOAR and Gemini. An outside firm also has been employed to help with estimates of construction costs at the various sites. This is part of the effort to identify potential cost issues, which is a source of concern. We have had discussions with the science working group centered around the following questions:

- What is a reasonable cost target for the ATST construction phase?
- What are reasonable options to consider if the intial cost estimates are too high?
- Can we think in terms of a modular approach for the design, allowing a functional contingency now and a future upgrade potential later?
- Can savings be achieved through a smaller system that provides most of the science desired? This is a trade of items such as achievable f ratio on the primary mirror, smaller lab space, smaller pier with telescope closer to the ground. Each of these could lead to lower costs, but may impact some of the science.
- What science requirements can be pushed back to future upgrades without impacting most of the science?

Cost comparisons at a detailed subsystem level were made using knowledge of real costs of similar subsystems and technology. The costs, based upon details from other projects, were normalized to current-year dollars, then inflated (3-4% per year) to 2008 dollars to reflect estimated costs during the construction phase. Several ideas are being pursued to find lower cost options. Some of these concepts come close to an inflation adjusted decadal survey target, but some trades as to the science accomplished may be required to lower the cost. Our project planning is taking an intermediate cost concept to develop "design to" cost targets for each major WBS element in the project planning activities. Once the design has evolved, appropriate contingency — monetary or functioning — will be added based upon an assessment of project risk. The project management and science teams are working together to prioritize the requirements and evolve the concept development to obtain the most important science drivers in a cost effective manner. Upgradeable concepts are being investigated to allow for future growth and additions to achieve more of the science goals in the future.

1.1.3 ATST Site Selection

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

The ASWG helped to determine ATST siting criteria, continues to verify the validity of the site testing procedures, and provide advice to the site survey scientist in developing a ranked list of the sites. This list will be presented to the Project Scientist who, after verifying — in consultation with the ASWG — that the science objectives of the ATST can be met, will recommend siting of the ATST to the NSO (Project Director). Once the Project Director has the Project Scientist's final recommendation for siting, he will make the final site selection in consultation with the NSF Astronomy Division.

Substantive progress on the site survey has been made over the past few months. As of June 2002, the following have been accomplished:

- Completion of the seeing monitor development.
- List of candidate sites finalized:
 - Big Bear Solar Observatory, California;
 - Mees Solar Observatory, Haleakala, Hawaii;
 - Observatorio Rouque de Los Muchachos, La Palma, Canary Islands, Spain;
 - Sacramento Peak, New Mexico;
 - San Pedro Martir, Baja California, Mexico;
 - Panquitch Lake, Utah.
- Installation and operation of three seeing monitors, one each at Sacramento Peak, Big Bear and Haleakala
- Completion of the permitting process for Panguitch Lake.
- Initiation of the permitting processes for La Palma and San Pedro Martir.
- Establishment of a contract with the University of Hawaii to develop and construct the Sky Brightness/Water Vapor/Dust Monitor.
- Completion of the first phase of the data reduction package.

1.1.4 Near-Term Plans

The near-term plans focus on two top-level items: project planning and conceptual design. Under project planning, the new WBS is being detailed to finalize the D&D program schedule. This includes major milestones such as reviews and preparation of the construction phase proposal, setting up the review process and working with the partnership to establish remaining work packages.

Project Planning

Each engineer responsible for a WBS is in the process of detailing the plans and schedules for individual areas within the WBS, including initial estimates of schedules and cosst estimates for the construction phase. The systems engineer, project and deputy project managers will lead integration of these details into the overall project WBS and schedule. Emphasis will be on near-term planning, but drafts of longer term plans through the construction phase are essential for keeping the end-project goals in mind. A preliminary schedule for the the major review milestones has been established.

Conceptual Design Review Plans

A conceptual design review is planned for spring 2003. In preparation for this design review, guidelines are being established with details on how major system level reviews and reviews in specific areas as required will be conducted. A list of potential reviewers has been established, from which a group of 6-8 engineers and managers will be selected. The ATST science community will be included in this process through the ASWG or their designees. This will ensure adequate coverage of engineering, science, and management considerations. The intent is for three such major reviews to be held during the design and development phase, beginning with the conceptual design review.

To prepare for this review, a telescope design workshop will be held in fall 2002. The workshop will include the partner community and potential members of the design review committee and should provide early feedback on overall direction toward the conceptual design review.

The following are draft priorities for the major reviews:

Conceptual Design Review (Spring 2003)

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

Preliminary Design Review (2004)

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

Critical Design Review (2005)

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

Design activities that will be included in the conceptual design phase are:

- Iterate beam transfer optics design concepts with partners.
- Systems modeling (thermal, optical, stray light, etc.).

Error Budgets are being established for several key observing scenarios including:

- Adaptive Optics (on-disk observations).
- Seeing limited (on-disk observations).
- Coronal observations (seeing limited).
- Polarization.

This will include initial top-down estimates to derive subsystem engineering requirements and bottoms-up estimates from concepts developed to find and eliminate problem areas and for purpose of evaluating concepts against the top level engineering and science requirements.

Targeted models will be produced in support of the major system trades including:

- Thermal control.
 - Seeing effects.
 - Alignment and mirror figure preliminary analysis.
- Stray light.
- Surface roughness.
- Dust and contamination.
- Cleaning and protection strategy.
- Baffling.

Design and analysis supporting the major trades will have a priority. These include telescope configuration, optical approach, enclosure concepts and instrument interface and facility requirements. The optical approach

includes off-axis designs and iterations with partners on potential instrument designs such as visible and near-IR spectral polarimeters that are consistant with the telescope and facility conceptual designs.

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

1.2 Adaptive Optics

Adaptive optics (AO) corrects for atmospheric distortion of the wavefront in order to achieve diffraction-limited imaging from ground-based telescopes. Recognizing the importance of AO for ground-based solar physics, NSO took the lead in developing low-order solar AO. NSO invested about \$1.2M in the development of a low-order (20 degrees of freedom) AO system. The NSO low-order AO system has become a major tool for investigating the fine structure of solar magnetic fields and their interaction with the dynamic solar atmosphere. The AO system provides a corrected image to several instruments available at the Dunn Solar Telescope (DST), such as the Advanced Stokes Polarimeter, the Universal Birefringent Filter and the dual Fabry-Perot system. Results obtained with the AO system can be viewed at http://www.nso.edu/AOWEB.

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

High-resolution observations of the Sun are essential in solving many of the outstanding problems of solar astronomy. The current high-resolution solar telescopes are in the one-meter class. These are limited because the Fried parameter (roughly speaking, the largest aperture telescope that would have diffraction-limited seeing) of a good daytime site is about 10 cm. To obtain full benefit from existing telescopes, one needs AO with more than 20 degrees of freedom. Going from the current low-order AO system, to a high-order, scalable system represents a major development effort.

The next step in fully compensating existing telescopes and for designing the AO system needed for the ATST is the development of a high-order AO system with 76 degrees of freedom (AO76). The AO system for the ATST will require about an order of magnitude more degrees of freedom. Such a system is adequate to achieve atmospheric compensation at the DST under median seeing conditions and diffraction-limited imaging in the near infrared under good seeing conditions at the McMath-Pierce Telescope. NSO is working with NJIT/BBSO to develop high-order systems that will be installed at the 76-cm DST on Sacramento Peak and at the 65-cm telescope at BBSO. These systems will upgrade leading high-resolution solar telescopes — greatly improving the scientific output of each. In the meantime, the adaptation of a low-order AO system at the NSO McMath-Pierce Solar Telescope will yield diffraction-limited imaging in the infrared. These upgraded telescopes will serve a broad solar community with diverse needs, from the individual university researcher to teams conducting campaigns.

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

have to be understood. AO technology and AO data-reduction tools have to be developed in order to be able to fully exploit the scientific capabilities of AO. Having high-order systems operating at two or three sites will enable us to investigate implementation of AO under the broadest of situations.

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

1.3 SOLIS

If all goes as planned, early in FY 2003 the SOLIS suite of instruments will be embarked on a program of producing high-quality synoptic solar data over a period that covers a few solar cycles. SOLIS (Synoptic Optical Long-term Investigations of the Sun) is a project to make optical measurements of processes on the Sun, the study of which requires well-calibrated, sustained observations over a long time period. The project was started in mid FY 1998 and completing it has taken about a year longer than originally planned. A major reason for the delay was an inability of a vendor to provide custom CCD cameras. Somewhat less capable cameras from another vendor were delivered in early March 2002 and are currently being tested and prepared for integration into the vector spectromagnetograph (VSM) instrument.

The suite of three instruments on one equatorial mounting will provide one arcsecond full-disk measurements of the photospheric vector magnetic field, the chromospheric longitudinal magnetic field, chromospheric intensity and Doppler velocities using several spectral lines, and clean continuum images. In addition, spectra of the Sun as a star will be obtained regularly. A major component of SOLIS is a powerful data handling facility that will deliver reduced data shortly after it is obtained. It also allows scheduling of special user observation programs interleaved with the regular synoptic program.

The SOLIS mounting, a robust equatorial cylinder with two independent declination axes, is in its final testing stage. The mechanical, electronic and optical components for the 50-cm aperture vector magnetograph are being installed in the instrument housing prior to final alignment and functional checks. This includes the long-delayed focal plane cameras. To meet this need, Rockwell Science Center produced two cameras using hybrid detectors that meet most of the original specifications. The 15-cm aperture full-disk filter imager is also nearing completion. It uses two birefringent filters to cover the wavelength range from 393 to 1083 nm. The 1083 nm filter is finished and produces excellent solar images. It was used in a recent community-wide high-cadence flare observing campaign to capture flare images at 30 frames per second. The other filter is still in the assembly stage.

The integrated sunlight spectrometer has been used to collect integrated sunlight spectra for more than a year. The data have been successfully used to develop advanced flat fielding algorithms to achieve high spectrophotometric precision. During this process, we found that it is necessary to rebuild a small part of the mechanical structure from invar. An extinction monitor is an integral part of this instrument. It provides low resolution full-disk solar images at four wavelengths. These images are used to determine how the terrestrial atmosphere affects uniform integration across the solar disk.

Cross-calibration observations with existing NSO synoptic instruments are planned for the near future. When these are completed, SOLIS will be moved to Kitt Peak where it will be mounted on top of the vacuum telescope building. Once SOLIS beings to produce high-quality data, NSO will propose to build two additional

SOLIS units in response to the desired capability outlined in the NRC ten-year plan, "Astronomy and Astrophysics in the New Millennium." These will be placed at distant longitudes (possibly Tenerife, Spain and a site in China) and operated in collaboration with foreign partners to form a SOLIS network capable of much more complete coverage of transient solar activity.

2 Instrumentation Program

2.1 Low-Order Adaptive Optics

The low-order adaptive optics (LOAO) system is completed and available for users requesting time on the Dunn Solar Telescope (DST).

The LOAO system can be used to feed a corrected image to the HAO/NSO Advanced Stokes Polarimeter (ASP) the Universal Birefringent Filter (UBF), the UBF combined with a Fabry-Perot filter for narrow-band imaging, dual IR and visible Fabry-Perot filters, and several other broad- and narrow-band imaging devices (G-band, Hα, K-line, white light). The corrected image can be fed to several of these devices simultaneously.

2.2 Advanced Stokes Polarimeter Upgrade

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

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

NSO and HAO are currently in the design process for Phase 2, integrating the DLSP with AO76. The optimistic completion target date for Phase 2 is August 2003.

2.3 Large-Format Infrared Array and Controller

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

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

A high-quality ALADDIN-III array has been identified and assigned to NSO by NOAO at no cost to NSO. A contract for the camera controller was signed with Mauna Kea Infrared (MKIR), and is nearing completion. In a collaboration with NASA, NSO will obtain a suitable initial science dewar. A funding source for the final science dewar has not been identified. The initial system should be ready for commissioning by early FY 2003.

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

2.4 McMath-Pierce Telescope Control System

Upgrades to the telescope control system (TCS) are needed to ensure that the facility remains competitive and maintainable. Until the end of FY 2003, only minor planning and test efforts are envisioned due to limited resources. The latter includes the the investigation of a new guider approach that will be finished and, if successful, commissioned during FY 2003. The TCS upgrade will take advantage of existing engineering experience within NSO, experience gained in the SOLIS project, as well as experience being gained with the commercial TCS of the upgraded East Auxiliary telescope.

2.5 Image Improvements at the McMath-Pierce

2.5.1 Seeing Improvement

Tests of potential improvements to the telescope seeing have been conducted during the last several years, which helps to understand internal seeing in a solar telescope, a crucial prerequisite for the design of the ATST. Further tests and modification will be driven by the need for more information for designing the ATST. The performance of such improvements will be assessed with a high-order wavefront sensor that has been developed for the adaptive optics project (see below).

2.5.2 Adaptive Optics

The infrared adaptive optics project at the McMath-Pierce telescope is making rapid progress. During FY 2002 the tip-tilt system was commissioned and made available for scientific use on a shared-risk basis. Every observing run with this system has provided spectacular new scientific insights, such as the detection of CO emission off the solar limb using the Fourier Transform Spectrometer. Those data indicate significantly lower temperatures in the chromosphere than previously thought. During FY 2003, the tip-tilt system will be converted into a fully supported user instrument. In parallel, the adaptive optics system with a 37-actuator mirror has been developed and is expected to deliver diffraction-limited images between 2.3 and 12 μ m by the end of FY 2002. During FY 2003, the system will be optimized and made available on a shared risk basis. Towards the end of FY 2003, the system will be available as a geneal user instrument.

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

1 NSO Telescope Operations

Ongoing upgrades to their focal plane instrumentation have allowed NSO telescopes to remain extremely productive and among the most useful solar telescopes in the world. Although the major NSO telescopes are three or more decades old, they still play a key role in support of US and international solar research. The NSO telescope upgrade and instrument development program is guided by the scientific and technical imperatives for a new ATST. Consequently, telescope and instrument upgrades and operations are reviewed and supported on the basis that they serve as necessary preludes to the ATST initiative while concurrently serving the needs of the scientific community.

1.1 Flagship Facilities

1.1.1 Dunn Solar Telescope

The 76-cm Dunn Solar Telescope, located on Sacramento Peak at an altitude of 2804 m, is the premier facility for high-resolution solar physics. It is an evacuated tower telescope with a 1.6-m secondary stopped down to 76 cm by the entrance window. The evacuated light path eliminates internal telescope seeing. The image enhancement program over the past few years has included active control of the temperature of the entrance window to minimize image distortion and high-speed correlation trackers to remove image motion and jitter. Its new, pioneering low-order adaptive optics system provides diffraction-limited images under good seeing conditions. A high-order system that will provide diffraction-limited seeing under moderate to poor conditions is being developed. NSO has pioneered solar adaptive optics and high-resolution, ground-based solar physics as a necessary prelude to the ATST.

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

NSO will vigorously pursue the opportunity presented by high-resolution, diffraction-limited imaging at the DST with a goal of refining ATST science objectives and requirements, and ensuring the growth of the expertise needed to fully exploit ATST capabilities. With the advent of AO, the DST has seen a large increase in proposal pressure and the over subscription rate has nearly doubled (currently ~50%). Major science topics that the DST is ideally suited to pursue include:

- Transient eruptions. Flux tube evolution and interactions that trigger activity.

- Origins of solar variability and atmospheric heating. Role of small-scale flux tubes, convection, and waves.
- Surface and atmospheric structure. Fields and flows in magnetic structures such as sunspots, pores, filaments, and prominences.

To support this science, the DST houses the wealth of instruments shown in the Table III-1.

1.1.2 McMath-Pierce Solar Telescope

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

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

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

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

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

The FTS is thus able to produce high-quality measurements of spectral line positions, strengths and widths. The McMath-Pierce FTS is a multi-disciplinary facility that is utilized for research programs in

solar physics, laboratory spectroscopy and atmospheric sciences. Results from FTS laboratory studies have been crucial to the interpretation of data derived from the Arctic and Antarctic ozone campaigns. The unique combination of a large solar telescope with infrared capability and a high-resolution FTS instrument is ideally suited for conducting atmospheric research at this facility. More than two dozen molecules in the Earth's atmosphere, which have been identified in the McMath-Pierce FTS solar spectra, are being monitored during each observational run. The McMath-Pierce facility has been designated as an official complementary site for the Network for the Detection of Stratospheric Change (NDSC). The Earth atmospheric measurements that are made at this facility are included in the NDSC archive.

1.1.3 Global Oscillation Network Group

The Global Oscillation Network Group (GONG) is an international, community-based project to conduct a detailed study of the internal structure and dynamics of the Sun using helioseismology. In order to exploit this technique, GONG developed a six-station network of automated and extremely sensitive and stable solar velocity imagers located around the Earth to obtain nearly continuous observations of the Sun's "five-minute" oscillations. Because the oscillations have very long coherence times (days to years), the major obstacle in utilizing helioseismology has been the interruption in the observations imposed by the day-night cycle at a single observatory. This break in data flow introduces a fundamental uncertainty in the determination of the period of the waves, as well as creating background noise that hides all but the strongest oscillations. GONG's network provides essentially continuous observations of the solar velocities, overcoming this obstacle by insuring that at least two sites can see the Sun at all times. This overlap minimizes data lost to bad weather or technical problems, and at the 90% coverage level the few remaining gaps can reliably be "filled in" to produce an essentially continuous data set. GONG's new 1024² pixel cameras obtain velocity, intensity, and magnetic-field images of the Sun's surface every minute. Once a week the data is shipped to project headquarters in Tucson, where the data from all six sites are calibrated and merged to obtain frequencies and other products, which are made available to the community.

In addition to the operation of the network, GONG has developed a data reduction and analysis system to process the observations, and facilitate the activities of the scientific community. After completing the camera upgrade project (GONG+) in 2001, the instruments now collect 16 times more individual picture elements and yield 32 times more data, including continuous magnetograms, than the "Classic" GONG system. In order to exploit the full scientific potential of the GONG+ data, the Project is undertaking another phase, GONG++, which will implement a high-performance data handling system and data processing pipeline system. The full-up system should become operational in FY 2003, followed by the development of analysis tools for local helioseismology applications.

Helioseismology is both a tool for probing the solar interior and a science in its own right. As a tool, the method utilizes waves that propagate throughout the Sun to measure its invisible internal structure and dynamics. There are millions of distinct, resonating acoustic waves seen by the Doppler shifting of light emitted at the Sun's surface. The periods of these waves depend on their propagation speeds and depths of their resonant cavities. The large number of resonant modes with different cavities allows us to construct extremely narrow probes of the temperature, chemical composition, and motions from just below the Sun's surface down to its very core. Results to date have substantially advanced our knowledge of the Sun's structure and dynamics, testing fundamental theories of physics and astrophysics, and we are now beginning to measure significant structural variation with the solar sunspot cycle, as well as on shorter time scales. With the increased spatial resolution of GONG+, we are also able to carry out local helioseismology, which uses traveling acoustic waves to study small-scale three-dimensional features below the Sun's surface.

NSO will operate the GONG network over a full solar cycle to refine its measurements of the time-averaged solar structure and to pursue the systematic variations in the structure of the solar interior with magnetic activity. GONG will continue to pursue opportunities presented by the GONG+ instruments and the GONG++ data handling system to ensure the advancement of the major topics in helioseismology, including:

- Global p-modes to high degree ($\ell \le 1000$). Global helioseismology to high spherical harmonic degree to probe closer to the solar surface.
- Local helioseismology. Local helioseismology to probe the inhomogeneous and intermittent structure and flows below the surface (tracking and remapping for time distance, ring diagrams, acoustical holography analysis).
- High-resolution, high-cadence magnetograms. Continuous, high signal-to-noise ratio, high spatial-resolution magnetograms will be of broad interest and extend the SOLIS data by providing a continuous temporal context.
- Far-side imaging. Near real-time images of the far side of the Sun will help forecast active
 regions up to two weeks before they rotate into view, providing help to a broad range of
 users ranging from solar astronomers planning upcoming observing campaigns to space
 weather forecasting.

1.2 Synoptic Facilities

1.2.1 Evans Solar Facility

The Evans Solar Facility (ESF) provides a 40-cm coronagraph as well as a 30-cm coelostat. The Evans coronagraph is the largest in the US and most thoroughly instrumented in the world. The ESF 40-cm coronagraph is currently used extensively by both NSO staff scientists and visiting astronomers for a wide variety of research projects (e.g., coronal heating, coronal electric fields, chromospheric and coronal magnetic fields, heliospheric structure prediction, and cyclic variation of coronal structure). The ESF has provided limits of electric fields in the solar atmosphere, and discovered the rush to the poles in coronal emission lines as well as the extended solar cycle in coronal emissions. The coronagraph feeds a universal spectrograph, spectroheliograph, Littrow spectrograph, chopping coronal photometer, and a bench where PI instruments can be set-up. Recent instrumentation includes a visible and IR coronal polarimeter, which has produced tantalizing observations of coronal magnetic fields. This new instrumentation will provide core capabilities for the next generation of ground- and space-based coronal telescopes. The ESF also provides full-disk spectroheliograms in several bandpasses near the Ca II K-line and Ha. There are no plans to upgrade these capabilities as these observations will be replaced by SOLIS. The USAF provides most of the operating support for the ESF.

1.2.2 Hilltop Solar Facility

The Hilltop facility houses the white-light and H α flare patrols, the coronal one-shot coronagraph, and a multiband solar photometer. In addition, it has a 10-arcsec coelostat that feeds an optical bench currently used by the USAF group at Sunspot in their development of the Improved Solar Observing Optical Network (ISOON) project. The SOLIS Full Disk Patrol (FPD) is intended to replace the white-light and H α patrols, so upgrades of these systems have been frozen.

Table III-1. Telescope and Instrument Combinations FY 2003

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

INSTRUMENT **COMMENTS/DESCRIPTION** TELESCOPE

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, $R \leq 40{,}000,\ 4200$ - $7000\ \mbox{\normalfont\AA}$
UBF-FabryPerot	DST	Tunable narrow-band filter, $R \leq 250{,}000,~4200~\textrm{Å}$ - $7000~\textrm{Å}$
Dual-FabryPerot	DST	Tunable narrow-band filter, R \leq 250,000, $$ 4200 Å $-$ 7000 Å, high transmission, current prefilters at 5576 Å and 6302 Å
Horizontal Spectrograph	DST	$R \le 500,000,~300~\text{nm}$ - 2.5 μm
Echelle Spectrograph	DST	$R \leq 2,000,000,\ 300\ nm \ \ 2.5\ \mu m$
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies
Littrow Spectrograph	ESF	$R \leq 1,000,000,\ 300\ nm$ - $2.5\ \mu m$
Various CCD Cameras	DST/ESF/HT	380 - 1083 nm, Formats: 256×256 to $2K \times 2K$
Correlation Tracker	DST	Tip/tilt correction
40-cm Coronagraph	ESF	$300 \text{ nm} - 2.5 \mu \text{m}$
Full-Limb Coronagraph	HT	Emission-line coronagraph
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å
Flare Patrol	HT	$\mbox{H-}\alpha$ and white-light full-disk $% \left(1\right) =1$ images, 1 min. cadence

NSO/Sacramento Peak - IR IMAGING & SPECTROSCOPY

Horizontal Spectrograph	DST	High-resolution 1 - 2.5 μ m 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 µm, R

 \leq 200,000

NSO/Kitt Peak - IR IMAGING & SPECTROSCOPY

Vertical Spectrograph	McMath-Pierce	0.32 - $12 \mu m, R \le 10^6$
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 μm , $R \approx 180,000$
IR Imager	McMath-Pierce	1 - 5 μ m, 256 \times 256, 12 Hz, imaging spectroscopy, polarimetry
CCD Cameras	McMath-Pierce	380 - 1083 nm, 576 × 384
ZIMPOL I	McMath-Pierce	$450 - 1100$ polarimetry, 10 Hz, 300×400

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1.2.3 Kitt Peak Vacuum Telescope

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

2 Digital Library and Virtual Solar Observatory

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic data sets over the Internet to the research community. Since the inception of the Digital Library in May 1998, close to 400,000 science data files have been distributed to about 13,000 unique computers. These figures exclude any NSO or NOAO staff members.

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

NSO has made its entire set of daily solar images from the KPVT, FTS data, and a portion of the Sacramento Peak spectroheliograms available on-line. The holdings of the NSO Digital Library are stored on robotic CD-ROM jukeboxes and are searchable via a Web-based interface to a relational database. SOLIS will soon begin to generate processed data at a maximum rate of 240 GB per day, with requirements for rapid archiving and user access. Thus, a higher capacity storage system is now in procurement and, when installed, will also hold the Digital Library contents.

In order to leverage further the substantial national investment in solar physics, NSO is participating in the development of a Virtual Solar Observatory (VSO) and the European Grid of Solar Observations (EGSO). The VSO, and its European counterpart the EGSO, will initially comprise a collaborative distributed solar data archive and analysis system with access through the World Wide Web. The overarching goal is to facilitate correlative solar physics studies using disparate and distributed data sets. Necessary related objectives are to improve the state of data archiving in the solar physics community; to develop systems, both technical and managerial, to adaptively include existing data sets, thereby providing a simple and easy path for the addition of new sets; and eventually to provide analysis tools to facilitate data mining and content-based data searches. None of this will be possible without community support and participation. Thus, the solar physics community is actively involved in the planning and management of the VSO. For further information, see the web pages at http://virtualsolar.org, and http://www.mssl.ucl.ac.uk/grid/egso/.

IV SCIENTIFIC STAFF

The primary roles of the NSO scientific staff are to carry out a balanced and forefront program scientific research, innovative instrument development, and observing support for the solar community. Through successful achievement in these multiple roles, the scientific staff is able to assume both a leadership role and a critical support role, in response to the needs and priorities of the community. In order to effectively carry out these roles, the responsibilties of a scientific staff member are divided between observatory service and scientific research. AURA policy establishes a goal of allocating 50% of an individual's time for the conduct of scientific research. Experience clearly confirms the AURA management view that maintaining a strong NSO scientific staff, with active research interests, is required in order to provide US solar physicists with the best solar facilities in the world.

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

1 Interior Structure and Dynamics

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

2 Solar Activity and Atmospheric Heating

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

NSO scientific staff pursue novel investigations of the solar chromosphere and corona in order to provide the observational framework for theoretical models of solar activity. For example, K. S. Balasubramaniam (Bala) will continue his efforts to understand the magnetic activity of the solar chromosphere using spectroscopic and polarimetric techniques. Bala, along with Han Uitenbroek, Jack Harvey and Harry Jones, is using the KPVT to conduct a careful study of the Zeeman splitting of the Ca II 854.2 nm line in order to more completely understand the magnetic influences on the formation of this chromospheric line diagnostic. Moreover, Han Uitenbroek and Bala are analyzing spatially and temporally resolved observations of the 854.2 nm line using the full Stokes capability of Uitenbroek's multi-dimensional radiative transfer code to significantly improve estimates of chromospheric magnetic field strengths. In addition, Bala and NSO Director Steve Keil will continue to analyze data acquired with the ASP during the previous solar maximum in order to delineate the velocity and magnetic field characteristics of active region evolution for solar activity modeling. Finally, the

link between the photosphere and the two-million-degree corona will be investigated by Alexei Pevtsov who will continue his work on the properties of X-ray bright points and the associated photospheric bipoles. Pevtsov will also examine the role of magnetic fields in coronal heating and the relationship between solar drivers and geomagnetic storms.

3 Solar Variability

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

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

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

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

4 Magnetic Fields and Atmospheric Structure and Dynamics

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

Thomas Rimmele leads the NSO solar adaptive optics program. Rimmele will continue his efforts to perform observations at the highest spatial resolution, using both AO and frame selection techniques in order to study the properties and the dynamics of small-scale magnetic elements. In a related effort, Christoph Keller is developing active and adaptive optics for the infrared for utilization at the McMath-Pierce main telescope. Keller has achieved encouraging laboratory results that he intends to extend to actual use at the telescope, ultimately culminating in a user AO system for IR observations at the McMath-Pierce in FY 2003. Furthermore, Keller will continue to use the McMath-Pierce facility to investigate scattering polarization in the photosphere and the chromosphere, which gives new insight into atoms and molecules and their radiation in the solar atmosphere and properties of weak, turbulent magnetic fields. Observations with the DST using adaptive optics in combination with phase-diverse speckle imaging will be used to study the dynamics of magnetic elements.

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

5 Laboratory Spectroscopy

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

6 NSO Outreach to the Community: A Brief Overview

Through the enterprise of its scientists, NSO has obtained substantial funding over the last decade for several major projects (GONG, SOLIS, AO and ISOON) that service the solar community. While these projects also involve major commitments of staff time to develop and operate, NSO scientists nevertheless remain scientifically productive as documented in the NSO annual report. To support the staff scientists'

research, while simultaneously contributing to the education of young scientists, NSO supports several graduate (SRA) and undergraduate students (REU) each summer to assist with observations and data analysis. NSO also holds one or two international workshops each year with topics that relate to staff research. These workshops are well attended (80-100 participants) and provide the NSO staff an additional chance to interact with other scientists in an informal and productive atmosphere.

V EDUCATION AND PUBLIC OUTREACH

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

Table V-1 shows the approximate level of support provide to the EPO program. In addition, NSO participates in and receives support from the NOAO's PAEO office (~\$85K). NSO makes resources available to support its EPO effort in the form of supplies and materials, computer workstations, WWW site, housing, Visitor Center and telescope time (~\$50K). The total funds devoted to the program including the ~5 FTE's shown in the table, \$80K from NSF for the REU and RET programs, the NOAO support and non-payroll is approximately \$350K or ~4.5% of the total NSO funding. Visitor Center revenues are about \$50K per year that go back into the Center operations and public exhibits. In the near future, this plan will include combined EPO efforts of NSO and its ATST partner institutions. NSO plans to add two EPO positions, one in FY 2002 to coordinate our EPO program with the ATST partnership consortium and one in FY 2003 to oversee and expand our current programs and to increase our awareness with the public.

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

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

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

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

NSO has participated in the NSF Research Experiences for Undergraduates (REU) program since the inception of the program in 1986. Each summer, approximately eight to twelve students — divided equally between the Tucson, Arizona and Sunspot, New Mexico sites — participate in the program at NSO. NSO also supports several graduate students from the US and abroad each year. The graduate

students receive excellent training and their presence enhances the experience of the REU students. Close working relationships are encouraged which allow the undergraduates to learn from the experiences of the older students as well as that of the on-site staff. There are currently eight REU students (four in Tucson and four at Sac Peak) and four summer graduate students at Sac Peak. NSO is participating in the summer 2002 Research Experiences for Teachers (RET) program. Four high school science teachers, three at Sac Peak and one in Tucson, are working with NSO staff scientists. NSO also participated in the Teacher Leaders for Research Based Science Education (TLRBSE) program with NOAO. NSO scientists in both Tucson and Sac Peak provided projects for the teachers and participated in their workshops.

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

2 K-12 Education

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

3 Other Public and Educational Outreach

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

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.

4 NSO Visitor Center

The National Solar Observatory at Sacramento Peak hosts approximately 35,000 visitors annually. Visits begin at the Sunspot Astronomy and Visitor Center (Visitor Center), where all the necessary visitor conveniences, including vending machines, a gift shop, host/hostess, and interpretive information are provided. 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 houses a wide range of interactive displays. These educate the visitor on topics related to the science and research being done at NSO and nearby Apache Point Observatory and to astronomy in general, and to the effect of the Sun on the Earth's environment.

The Visitor Center is virtually self-supporting through revenues from its gift shop and small admissions fee. Currently, revenues from the gift shop are sufficient to pay for all cost of goods sold, for supplies, materials, and personnel required for operation of the Center. As revenues from the Center increase, they will be invested in improved outreach programs such as expanding the number of guided tours and providing more Web-based classroom projects based on solar data.

5 NSO Public Web Pages

The NSO WWW site (http://www.nso.edu) contains several public outreach areas. These include a live solar image that is updated once per minute so the public (and the scientific community) can see how the Sun is behaving in $H\alpha$. These images allow the observer to quickly assess the state of solar activity. Virtual tours of the NSO sites, including telescope descriptions, are available. There is an interactive solar tutorial that provides information about the Sun and its processes. There is also an "Ask Mr. Sunspot" area where questions can be asked about the Sun and astronomy in general. Answers are posted on the 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.

VI MANAGEMENT AND BUDGET

1 NSO Organization

The NSO is a programmatically independent observatory managed by AURA, Inc. under contract to the NSF. NSO, however, continues to obtain services from NOAO. Currently, NSO is divided into two major administrative divisions, NSO/Sacramento Peak (NSO/SP) and NSO/Tucson (NSO/T), and a division to operate the Global Oscillation Network Group, NSO/GONG. During FY 2002 a new Project Office was formed to oversee the development of the ATST. NSO also has project groups for the NSF-funded AO and SOLIS programs, and for the Improved Solar Observing Optical Network (ISOON), which is funded by the USAF.

NSO has 70 permanent employees, including unfilled positions, 9 project employees working full-time on ATST, and 6 project employees working on SOLIS. An additional 24 employees who work at NSO and its facilities are paid by funds from the AF, NASA, and other partner institutions. In addition, NSO shares support personnel (shops, facilities maintenance, computing, administration) with NOAO in Tucson and on Kitt Peak. A complete set of organizational charts is shown in Appendix H.

The NSO Director's office consists of two employees, the Director and an executive assistant. The Director currently maintains his residence at NSO/SP. A site director for NSO/T also serves as deputy director. The NSO Director is also the ATST Principle Investigator. NSO/SP has a site administrator to manage operations and facilities. In addition, the NSO Director shares support personnel with the NOAO for accounting, human resources, graphics, educational outreach, etc.

NSO/SP operates several telescopes on Sacramento Peak in New Mexico as well as office, computing, instrument development and housing facilities for visitors and the resident scientific staff. Major projects at NSO/SP include development of site survey instruments for the ATST, adaptive optics, and development of 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 polarimetry techniques that can take advantage of high-resolution facilities. Currently there are 48 personnel at NSO/SP. There are 32 permanent NSF-funded employees, 6 permanent AF scientists, 4 AF-funded NSO employees working on the ISOON project, 2 research fellows and 4 students funded by NJIT working on high-order adaptive optics.

NSO/T operates the solar telescopes on Kitt Peak, offices in Tucson, and conducts projects at the Tucson facilities. NSO shares support personnel with KPNO on Kitt Peak and with the other NOAO divisions in Tucson. Major projects at NSO/T include SOLIS and IR camera development. NSO/T also conducts experiments and minor projects to improve Stokes polarimetry techniques, solar-stellar observation techniques, and speckle imaging techniques. NSO/T has 16 permanent NSF-funded staff, 6 NSO employees funded by SOLIS, and 7 funded by NASA and other sources working on data archiving and other projects.

NSO/GONG operates and maintains the GONG network of six telescopes, collects and processes the data, and makes the data available to users. Processing of the higher resolution data that is now delivered by the upgraded GONG cameras has resulted in a transition of instrumentalists to data analysis and science personnel. NSO/GONG currently has 20 NSO employees and 2 employees funded by NASA.

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NSO/GONG operates and maintains the GONG network of six telescopes, collects and processes the data, and makes the data available to users. Processing of the higher resolution data that is now delivered by the upgraded GONG cameras has resulted in a transition of instrumentalists to data analysis and science personnel. NSO/GONG currently has 20 NSO employees and 2 employees funded by NASA.

As NSO fully establishes independent operations and begins development of the ATST, the management structure will evolve over the next few years. When the ATST is completed, NSO will completely reorganize, and consolidation of resources will occur.

2 FY 2003 Spending Plan

The NSO base budget received from NSF in FY 2002 was \$7.97M, which includes \$1.115M embedded in the NOAO program for services and support and \$159K for the AURA management fee. The NSO program also relies on support from KPNO for operations and maintenance of its telescopes on Kitt Peak. The exact value of this support varies from year to year, depending on the required maintenance levels, and is embedded in the cost of operating Kitt Peak by KPNO.

Table VI-1 summarizes the funding NSO expects to receive in FY 2003. The NSO program was developed assuming level base funding of \$7.97M and anticipated funding for the ATST project of \$2.4M from NSF/Astronomy Division and 200K from NSF/Atmospheric Division. NSO also receives operational

Table VI-1. NSO FY 2003 Funding					
(Dollars in Thousands)					
NSF Base Program Funding	7,969				
ATST Project	2,600				
AFRL Support for Sac Peak Operations	450				
NASA Support for Kitt Peak Operations	32				
REU/RET Program	80				
ISOON Project (USAF)	TBD				
Revenue	176				
Total Program	\$11,307				

support from the Air Force Research Laboratory, under an MOU between the AF and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NASA provides operational support for the KPVT on Kitt Peak. NSO earns revenue from operation of the cafeteria, the Visitor Center, and housing on Sacramento Peak. These funds are used to support the operations that generated them.

The NSO budget is allocated to the various tasks NSO must perform to fulfill its mission. Although the budgets for specific tasks and programs are determined through a work breakdown structure, the actual allocations occur in functional units (Sac Peak, Tucson, GONG, projects, and the Director's office) as a means of assigning responsibility and budget authority. Table VI-2 summarizes the planned spending by functional unit and Figure VI-1 shows the percentage of the programming going to each area.

Table VI-2. NSO FY 2003 Planned Spending by Functional Area

(Dollars in Thousands)

	NSF Base
Director's Office ¹	352
AURA Corporate Fee	159
Educational & Public Outreach ²	256
Tucson/Kitt Peak ³	1,842
Sacramento Peak ³	2,269
GONG	2,693
ATST D&D Project	2,600
ATST In-house Contribution ⁴	835
NSO/SOLIS	300
ISOON Project Support	TBD
Total NSO Program	\$11,307

- 1 Contains \$18K of programmed indirects.
- 2 Combines the EPO funding at Sac Peak, Tucson, and EPO support received from NOAO.
- 3 All scientific staff salaries are contained in the Tucson, Sac Peak, and GONG allocations; \$416K to ATST from NSO/SP and \$190K from NSO/Tucson.
- 4 This number represents in-house personnel working on ATST-related technology, the ATST site survey, and ATST design and non-payroll support of these efforts.

All of the scientific staff salaries in Table VI-2 are contained in the Tucson, Sac Peak, and GONG allocations. Thus the table does not show the full effort devoted to the EPO program and the major projects since several scientists will devote a substantial fraction of their time to these programs. The table in Appendix C summarizes the complete NSO budget in more detail.

Tables VI-3 to VI-8 break out the spending plan for the major functional units in more detail. The funding summarized on the outreach line of Table VI-2 that is spent in each functional area is shown at the end of each table. The outreach support received from NOAO for the programs in Tucson and at Sac Peak is shown in the table for the Director's office.

Table VI-3 presents the Director's office budget. Some of the indirect amounts earned from non-NSF funded projects are budgeted towards operation of the Director's office. Non-payroll expenses include travel, supplies and materials, and other miscellaneous expenses. Committees include the semi-annual meetings of the Users' Committee and support for other committee meetings as needed to support management of the observatory.

Table VI-3. Director's Office (Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
Staff	249	40	289	
Committees	0	10	10	
NOAO Support	40	14	54	
Total Director's Office	\$289	\$64	\$353	
Outreach Support from NOAO	70	16	86	

Table VI-4 shows the break down for Tucson operations. The \$32K received from NASA supports the operation of the KPVT and will support SOLIS when the KPVT is decommissioned and SOLIS begins operations. Most of the instrument development program will be devoted to putting the ALADDIN array infrared camera on-line.

FY03 Total Spending (\$11,307K)

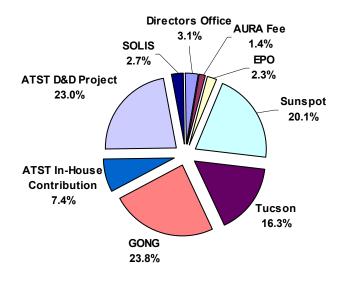


Figure VI-1

Table VI-5 breaks out the Sacramento Peak operations. Instrument development is concentrating on adaptive optics and upgrades to focal-plane instrumentation so users can take full advantage of diffraction-limited imaging. The Sac Peak administrative staff oversees site operations, visitor support, purchasing, shipping, receiving and budgeting. The facilities include costs for buildings (telescope facilities, offices, shops, civil engineering facilities, and administrative facilities), grounds, maintenance, utilities, housing (funding for housing support comes from rental revenues), water and sewage treatment, site snow removal and road maintenance.

Table VI-4. NSO/Tucson

(Do	(Dollars in Thousands)						
	Payroll	Non-Payroll	Total				
Scientific Staff	722	43	765				
Software Support	166	10	176				
Instrument Development	180	5	185				
NOAO/ETS → NSO	102	0	102				
Telescope Operations	121	21	142				
NOAO Support	350	122	472				
Total NSO/Tucson	\$1641	\$201	\$ 1842				
Outreach (REU/RET)	30	10	40				

Table VI-5. NSO/SP

(Dollars in Thousands)

	Payroll	Non-Payroll	Total
Scientific Staff	378	30	408
Scientific Support/Computing	140	108	248
Instrument Development	313	98	411
Telescope Operations	191	26	217
Facilities	289	309	598
Administrative Services	206	20	226
NOAO Support	141	20	161
Total NSO/SP	\$ 1658	\$611	\$2269
Outreach (REU/RET, SRA, Visitor C	Ctr.) 81	49	130

Table VI-5 contains the \$450K contribution of the USAF as well as the revenues earned from housing, meal services, and Visitor Center sales. The USAF funding is added to the general operations funding of the NSO to offset the support given to the Air Force Research Laboratory program at Sac Peak. Table VI-6 gives a breakdown of how these funds are used to support the AFRL program.

Table VI-6.	Air Force FY	' 2003 Funding
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(Dollars in Thousands)

(= ************************************					
	Payroll	Non-Payroll	Total		
Scientific Support/Computing	55	29	84		
Telescope Operations	28	5	33		
Instrument Development	100	25	125		
Facilities	74	76	147		
Administrative Services	48	10	58		
Total Air Force	\$305	\$145	\$450		

Table VI-7 summarizes the GONG spending plan for FY 2003. The increased cost of collecting and processing the high-resolution data is reflected in the DMAC and telescope operations budgets. Although the table does not show an outreach line, the GONG scientific staff participate in the outreach program and receive support from the NOAO outreach line shown in the Director's office budget (Table VI-3).

Table VI-7. NSO/GONG				
(Dolla	rs in Thousands,)		
	Payroll	Non-Payroll	Total	
Scientific Staff	270	25	295	
DMAC Operations	492	496	988	
Telescope Operations	288	625	913	
Administrative Services	144	10	154	
NOAO Support	240	103	343	
Total GONG	\$1434	\$1259	\$2693	

SOLIS spending will include planned carryover from FY 2002. This reflects both the fact that SOLIS began late in a fiscal year and the delays encountered on camera delivery from vendors. Because of a delay in the delivery of the PixelVision camera, SOLIS has implemented a contingency camera system.

Table VI-8. NSO/SOLIS							
(Dolla	rs in Thousands)						
	Payroll	Non-Payroll	Total				
Construction In-House	100	0	100				
Operations	50	150	200				
Total SOLIS	1						

2.1 ATST Program

Table VI-9 summarizes both the NSO in-house investment in the ATST and the ATST project funding NSO expects to receive in FY 2003 from NSF/AST. The NSO in-house contribution to the ATST includes development of an adaptive optics design that will be scalable to the large aperture of the ATST; investment in IR camera technologies needed to use the ATST in the 1.0- to 28-micron wavelength range; support for technical trade studies for heat control, scattered light, telescope contamination issues and off-axis design; and support for the site survey operation. Additional funding for the ATST is being provided by NSF/ATM to support HAO's participation in the project. This funding is shown separately in Table VI-10. It covers the development of an instrument design for a visible light polarimeter and participation in the design of an IR polarimeter led by the University of Hawaii.

The design and development phase of the ATST project covers five years, beginning in the last few months of 2001 and ending in early 2006. The D&D phase will be followed by a four- to five-year construction phase that is planned to begin in FY 2006. A design and proposal for the construction costs are the main products of the D&D phase. The conceptual telescope design and most of the preliminary design will be completed in-house with the collaborators providing input to the telescope design and designs for the major

instruments. Detailed designs of major components will be subcontracted. Whenever cost effective, we will re-use existing optical, mechanical, and electrical designs that can meet our scientific requirements.

Table VI-9. NSO/ATST							
(Dollars in Thousands)							
	Payroll	Non-Payroll	Total				
In-House Contribution							
ATST Tech Trade Studies	100		100				
Adaptive Optics	236	80	316				
IR Camera	50	90	140				
Site Testing	50	217	267				
Total In-House Contribution	\$436	\$387	\$823				
ATST D&D Project Funding							
Project Office/Sys Engineer	624	247	871				
Design Groups	548	454	1002				
Collaborator Subcontracts (Design)	300	48	348				
Collaborator Subcontracts (Site Survey)	127	22	149				
HAO Subcontract (ATM Funding)	130	100	230				
Total D&D Project	\$1,729	\$ 871	\$2,600				
Total ATST	\$2,165	\$1,258	\$3,423				

Table VI-10. HAO ATST FY 2003 Spending Plan (ATM Funding)				
(Dollars in Thousands)				
	Payroll	Non-Payroll	Total	
Visible Light Polarimeter	120	90	210	
IR Polarimeter (with Hawaii)	10	10	20	
Total HAO ATST Program	\$130	\$100	\$230	

2.2 Funding Priorities

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

1. Operate NSO flagship facilities until they are replaced by an Advanced Technology Solar Telescope.

Supporting US solar astronomers to obtain high-resolution observations in the visible and IR is critical if NSO expects to have users who will exploit the science capabilities of the ATST. Given that NSO facilities are still the world's best in many aspects and that we currently enjoy a lead in solar adaptive optics, IR technology development, solar synoptic observations, and coronal spectral line observations, we should continue to utilize these strengths. To continue ATST progress, NSO will:

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

2.3 Unfunded Needs

The NSO long-range plan (FY 2003-2007, in the AURA recompetition proposal) requested funding to add postdoctoral positions for supporting high-resolution science and ATST science goals, an educational outreach (EO) position for NSO to develop and coordinate NSO and ATST outreach programs, and funds to bring the ATST effort up to the amounts in the original proposal. In FY 2003, these requests amounted to \$200K for postdoctoral positions and an EO officer and \$1.4M for the ATST design effort.

Given the level funding anticipated between FY 2002 and FY 2003, NSO reduced its overall manpower by about 3% going into FY 2003. This impacts our ability to provide in-house support both to operations and the ATST. The \$1.4M request (or fractions thereof) for the ATST D&D effort would permit NSO to more fully staff the ATST project, pursue more thorough modeling/trade studies of critical technologies (primary and secondary mirror properties, scattered light, heat rejection models), and to fully fund the partner activities for instrument design and optical properties of off-axis systems. It would also help relieve part of the pressure on NSO's current program of user support and key instrument development (AO, Diffraction-Limited Stokes Polarimeter, IR technologies) by removing the need to use NSO personnel to fill the missing expertise within the ATST design team. The end result of an enhanced funding level will be a more complete design package and thus less risk in the cost estimate for the construction phase, and better support for current NSO users who will ultimately be the main ATST users.

APPENDIX A: MILESTONES FY 2003

A1. Advanced Technology Solar Telescope

The most important goal for NSO is the construction of an Advanced Technology Solar Telescope, which will achieve high-resolution imaging (0.1 arcsec) in the optical on a regular and sustained basis. The ATST also will be capable of operating in the thermal infrared. Key activities include developing the science requirements in detail sufficient for conceptual design, evaluating potential sites, and developing adaptive optics and infrared instrumentation. Specific milestones for the ATST and related instrumentation programs include the following:

- Complete the formation of an ATST Design Team.
- Perform the critical trade studies.
- Collect and analyze one year of data with the site survey telescopes.
- Develop funding partnerships for the construction phase.
- Hold a concept design review (CoDR) in spring 2003.

A2. Solar Adaptive Optics

- Complete opto-mechanical installation at the DST in November 2003.
- Schedule an engineering run at the DST in December 2003.
- Begin opto-mechanical installation at BBSO in December 2003.
- Schedule engineering runs at BBSO and the DST from February through June 2003.
- Initiate commissioning phase with science runs in July/August 2003.

A3. Diffraction-Limited Stokes Polarimeter (formerly Advanced Stokes Polarimeter Upgrade)

- Complete the Phase 2 design.
- Construct the modulator package.
- Interface the high-speed camera.

A4. SOLIS

- Complete testing at GONG site.
- Complete program of cross calibration for ISS and VSM.
- Move SOLIS to Kitt Peak.
- Start initial operations.
- Fix initial startup problems.
- Submit a plan for developing a SOLIS network through partnerships

A5. GONG

- Rebuild light-feeds and other subsystems in the network instruments.
- Procure remaining components and implement the GONG++ high-performance computing system.
- Design and commence implementation of the GONG++ data handling system and pipeline architecture.
- Continue development of analysis software for high- ℓ global p-mode processing, for local helioseismology applications, and for high-resolution, high-cadence magnetograms.

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

A6. Solar Infrared Program

- Conduct acceptance tests of ALADDIN camera controller and initial dewar. These tests will include spectroscopy at 1083 nm (He I) and 4667 nm (CO molecule) and spectropolarimetry at 1565 nm (Fe I).
- Conduct initial observations as a facility instrument. The ALADDIN system will be open for shared-risk observations for six months during FY 2003 by NSO users. At least four user observing runs will be planned.
- Develop science-grade dewar specifications. Requirements for the permanent closed-cycle cooled ALADDIN dewar will be written and a strategy to fund the purchase will be developed.
- Develop the polarimeter. Current polarimeter hardware will be tested and new hardware may be purchased if needed for polarimetry in the 1000-2300 nm wavelength range. Initial tests of polarimetry in the 3000-5000 nm range will be done and specifications for a user polarimeter in this range will be written.

APPENDIX B: STATUS OF FY 2002 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2002 Program Plan. (FY 2002 milestones appear in italics below.)

B1. ATST

Complete the formation of an ATST project office and recruit the ATST design team.

The core ATST project team has been hired and several NSO employees have been assigned duties within the ATST project.

Implement the critical trade studies, begin designing the telescope, prepare for conceptual design review. Most of the critical technology areas have been identified. Plans for evaluating the trade-offs are now being put in place. Several ideas for heat stops have been investigated and work on the thermal loading of the mirrors is underway. Implications of several off-axis design and f-ratio concepts for overall telescope cost and size have been studied. A few optical transfer concepts and location of the AO package have been analyzed. A design review team is being organized.

Complete the deployment of the site survey telescopes.

Telescopes were deployed at BBSO, Haleakala, and Sac Peak. The Panguitch Lake and La Palma tower and instruments will be deployed in the summer of 2002. Preliminary testing of the San Pedro Martir site is underway.

Develop statements of work for collaborating institution and negotiate sub-awards.

MOU's for sub-awards have been established with HAO, the University of Hawaii, the New Jersey Institute of Technology, the University of California San Diego, and the University of Chicago. HAO's effort is to design the visible light polarimeter and to collaborate with the University of Hawaii on the IR polarimeter. NJIT is designing an IR filter system. UCSD is providing scattered light studies for components of the telescope and heat stops. The University of Chicago is providing an engineer for the ATST site survey.

B2. Solar Adaptive Optics

Complete the high-speed camera.

Delivery of the camera is scheduled for the end of September 2002.

Complete the wavefront sensor.

The wavefront sensor will be completed by September 2002.

B3. Advanced Stokes Polarimeter Upgrade (currently Diffraction-Limited Stokes Polarimeter)

Complete the spectrograph design.

This was accomplished in spring 2002. The Phase I instrument saw first light on 13 March 2002.

B4. SOLIS

Complete assembly and testing of the VSM, ISS, FDP and EM instruments.

The mechanical and electrical assembly of the VSM are complete. The VSM is currently in a clean air facility and optics are being installed. An alignment procedure was developed and will be implemented starting mid-June 2002. All moving mechanisms have been tested and mounted in the instrument. Liquid cooling and helium pressurization tests have been passed. VSM assembly is expected to be complete by the end of July 2002.

The ISS requires that a small metal piece be replaced by one made of Invar. The ISS has been collecting test data for more than a year. These data were used to make major speed and accuracy improvements to a standard flat fielding algorithm. The ISS will remain in its present location until late in 2002 when it will be moved to Kitt Peak. Its extinction monitor is being assembled and tested.

The FDP instrument housing is nearly finished being fitted with all of its internal mechanical and electronic components. The moving mechanisms have all been tested successfully. The 1083 nm filter was used in a Tucson lab to acquire high cadence images of flares as part of an international observing campaign. The tuneable 380-660 nm filter is still being assembled.

Complete testing of the SOLIS mount, VSM and FDP at GONG farm.

Delayed. Due to begin summer of 2002.

Complete program of cross calibration programs for ISS and VSM.

Delayed. Due to begin late summer of 2002.

Complete the quick-look and first-order data reduction programs.

Nearly completed.

Start work on PCA reduction of VSM data.

This work was started but after investigation it became clear that a more traditional approach gave better results – at least as presently implemented.

Commence use of a DS3 data line from Kitt Peak to Tucson and move SOLIS to Kitt Peak.

DS3 line is installed and working. Move delayed until late 2002 or early 2003.

Start initial operations.

Delayed until late 2002 or early 2003.

Fix initial startup problems.

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

Submit a plan for developing a SOLIS network through partnerships.

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

B5. GONG

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

The GONG stations continue to operate reliably. Over six years of GONG data from the six-site network have been processed and made available to the community.

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

The implementation of the GONG++ high-performance computing system — server, on-line disk storage, and tape library — was begun at year-end FY 2001. The remaining components will be purchased at year-end FY 2002. The full-up system should be operational in FY 2003. Refinement of the GONG+ merging software is nearly complete and initial development of the tracking and remapping software for local helioseismology applications has begun.

The data processing pipeline system developed and used by the Space Telescope Science Institute for processing Hubble Telescope data (OPUS) has been selected as the support environment for the GONG++ data handling system's pipeline architecture.

B6. Infrared Array and Controller

Accept delivery of the ALADDIN camera controller from vendor and carry out acceptance tests at the McMath-Pierce Telescope.

Delivery is planned for late calendar year 2002. Two weeks of observing time at the McMath-Pierce will be scheduled for this delivery.

Initiate software development for specialized camera functions such as vector polarimetry and image selection.

Initiate software development: initial code for controlling Meadowlark optics polarimetric devices has been completed as part of the CSUN-NSO Ircam project. Tests of NIM polarimetric optics is scheduled for September 2002, and development of ALADDIN-specific code will begin after these tests. No progress has been made on frame selection software per se, although code developed for the ATST site survey instrument is likely to have applications.

APPENDIX C: NSO FY 2003 BUDGET & STAFFING SUMMARY

NSO FY2003 Budget Summary

Notes: nothing shown transferred to ATST or SOLIS							
	Directors						
	Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total Budget
Director	298,899						298,899
Scientific Staff		408,170	764,499	294,513			1,467,182
Sci Support/Computing		247,836	176,218	988,149			1,412,203
Instru Devel/Maint		410,846	286,686		567,988	200,000	1,465,520
Telescope Ops		217,378	142,480	912,880			1,272,738
Facilities		598,161					598,161
Admin		226,059		154,162			380,221
Grad. Student Program		20,000					20,000
Educational Outreach (REU/RET,K-12 etc)	85,785	55,000	40,000				180,785
Visitor Center/Public Outreach		54,977					54,977
Construction						100,000	100,000
Site Testing					267,000		267,000
NOAO Operations Support	53,616	160,847	471,988	343,140			1,029,591
ISOON Support ¹		TBD					-
LMT Operations ¹							_
Aura Management Fee	159,100						159,100
ATST Proposal (Astronomy Division Funds)	ŕ				2,400,000		2,400,000
ATST Proposal Atmospheric Division Funds)					200,000		200,000
High Order AO Proposal (MRI) ²							-
Total NSO Program	597,400	2,399,273	1,881,871	2,692,845	3,434,988	300,000	11,306,376
Revenues							
NSF MRI							0
NSF ATST Proposal (Astronomy Division)					(2,400,000)		(2,400,000)
NSF ATST Proposal (Atmospheric Division)					(200,000)		(200,000)
Programed Indirects	(17,887)						(17,887)
Housing Revenue		(91,000)					(91,000)
Meal Revenue		(16,720)					(16,720)
NSF/REU Funding		(40,000)	(40,000)				(80,000)
AF Support for Sac Peak Operations		(450,000)					(450,000)
AF Support for ISOON Project		TBD					0
Nasa Support for Kitt Peak Obserations			(32,000)				(32,000)
Nasa Support for Liquid Mirror Telescope							0
Visitor Center Revenue		(50,000)					(50,000)
Base Program - NSF Astronomy	579,513	1,751,553	1,809,871	2,692,845	834,988	300,000	7,968,769

Notes

FY 2003 STAFFING SCHEDULE

(In Full-Time Equivalents)

Director's

	Office	Sunspot	Tucson	ATST	GONG	SOLIS	Total
Scientists	1.00	4.00	6.50		4.00		15.50
Engineering/Scientific Programmers		7.00	5.00	5.80	7.75	3.25	28.80
Administrative Staff	1.00	5.00	1.00	3.00	2.00		12.00
Technical Staff		7.00	4.00	1.00	6.00	2.50	20.50
Maintenance & Service Staff		8.50					8.50
Total	2.00	31.50	16.50	9.80	19.75	5.75	85.30

¹⁻ Anticipated Funding to support AF ISOON Project

²⁻ Funding goes to NJIT for joint NJIT/NSO/KIS/USAF adaptive optics program

APPENDIX D: SCIENTIFIC STAFF RESEARCH AND SERVICE

Karatholuvu R. Balasubramaniam, Associate Astronomer

Areas of Interest

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

Future Research Plans

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

Research Thrust Areas and Recent Research Results

- 1. Understanding the influence of magnetic fields on chromospheric spectral line formation. (a) Using a combination of observed data from the NSO/SP spectromangetograph, and radiative transfer modeling of chromospheric spectral lines, Bala is working with NSO colleagues H. Uitenbroek, J. Harvey, and H. Jones (NASA/GSFC) in the interpretation of observed chromospheric Ca II 854.2 spectral line formation in solar activity. (b) Bala has been working on efforts to understand the magnetic activity of the solar chromosphere from full Stokes spectroscopy and polarimetric studies, simultaneously using photospheric and chromospheric lines. The advanced stokes polarimeter is used for these measurements. The spectral lines used are the photospheric spectral line pair Fe I 6301.5, Fe I 6302.5, Mg I 5172 and H I 6562.8. He is working with M. Eydenberg (New Mexico Tech) on characterizing the radiative transfer of these chromospheric spectral lines in a magnetic field.
- 2. Structure of Sunspots. (a) Bala is working on understanding the thermal and magnetic structure of sunspots using the dual-FP imaging filtergraph. He is comparing the various methods of inferring the thermodynamical nature of sunspots, including spectral line bisector analysis, and fitting functions to spectral lines. (b) Chromospheric super-penumbral structure. Collaborating with A. Pevtsov and J. Rogers (Cloudcroft Middle Schools, NM), Bala is working on developing a statistical structure of sunspot super-penumbrae from a large historical data set of H-alpha observations of the chromospheric superpenumbrae. The results will reflect on the helicity and the nature of twist in superpenumbrae which in-turn will be useful in constructing MHD models of an extended sunspot. (c) Using high-resolution imaging at the DST, as well as Stokes spectropolarimetry from the ASP, Bala is working on understanding the dynamic structure of sunspots in the photosphere and the chromosphere. The magnetic structure of sunspot penumbra and superpenumbrae in the chromosphere, as well as its evolutionary nature is not a well understood problem. The manifestations of the inverse Evershed effect and its relationship to the observed chromospheric magnetic fields is still a challenging problem and Bala hopes to address these issues using these data.
- 3. Solar Activity. (a) Bala and S. L. Keil will continue to analyze data acquired during the previous solar maximum to seek velocity and magnetic field characteristics of active region evolution for solar activity modeling. This includes data obtained with the narrow-band filter and the ASP. Bala is also working on the role of magnetic field in heating process in solar active regions. (b) He is collaborating with D. Byers (U. Utah) in understanding the energy release process in solar flares and solar mass ejections. (c) Bala will continue to work on the the goal of understanding high-resolution structure of active region filaments and

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

4. ATST. (a) Imaging Narrow-Band Filter. Working with G. A. Gary (NASA/MSFC) and M. Sigwarth (KIS), Bala will continue to exploit observing techniques and the importance of filter imaging with dual-FP and triple-FP cascaded Fabry-Perot Etalons. (b) With H. Uitenbroek, Bala is attempting to characterize the instrumental influence of spatial and spectral resolution and the resulting translation to the ATST design parameters. In collaboration with G. 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.

Service

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

Michael Dulick, Assistant Scientist

Areas of Interest

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

Future Research Plans

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

Service

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

Mark S. Giampapa, Astronomer

Areas of Interest

Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

Recent Research Results

Giampapa and his colleagues, R. Radick (AFRL), J. Hall (Lowell Observatory), and S. Baliunas (SAO), have completed a survey of chromospheric Ca II H and K line emission in solar counterparts in the solar-age and solar-metallicity open cluster M67, using the WIYN telescope with the Hydra multiobject spectrograph on Kitt Peak. The results indicate the range of potential amplitudes of the solar cycle through observations of

about 100 sun-like stars. This is critical to know in view of the impact of solar variations on long-term global climate changes. The survey results will be submitted for publication in FY 2003. 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. In collaboration with T. Fleming (Steward Observatory, U. of Arizona), Giampapa is analyzing Chandra data on low-mass stars. Thus far, their work has produced a detection of quiescent coronal X-ray emission in the lowest mass star yet seen in the X-ray, VB 10. J. Schmitt (Hamburg), M. Giampapa and T. Fleming submitted a proposal to the XMM Guest Investigator program to extend their work on X-ray observations of brown dwarfs and low mass stars near the critical mass limit for hydrogen core burning.

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

In collaboration with Dr. Eric Craine (Western Research & GNAT, Inc.), R. Tucker (NSO/GONG) and an REU student, Adam Kraus (University of Kansas), Giampapa continues to investigate the application of small, robotic telescopes equipped with CCDs for high-precision photometry of solar-type stars in clusters such as M67. The scientific objective is to measure 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. As NSO Deputy Director, Giampapa assists the NSO Director in the development of program plans and budgets, including budgetary decisions and their implementation.

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

John W. Harvey, Astronomer

Areas of Interest

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results

During FY 2002, J. Harvey concentrated on SOLIS and the upgrade of GONG, leaving little time for scientific research. However, in preparation for SOLIS data, he used KPVT data to explore the possibility of forecasting space weather events at Earth. One-day difference images of the Sun in 1083 nm revealed many changes including distinctive ones associated with CMEs. Using the difference between nearly simultaneous chromospheric and photospheric magnetograms he found that large-scale chromospheric fields may be useful in predicting the north-south direction of CME-associated magnetic clouds as they hit the magnetosphere.

This is a strong indicator of geomagnetic storm strength. A number of research projects are suspended, pending the completion of SOLIS.

Future Research Plans

During FY 2003, J. Harvey will continue to concentrate on the SOLIS project and, consequently, it is again unlikely that any significant research will be accomplished.

<u>Service</u>

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

Carl J. Henney, Assistant Scientist

Areas of Interest

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

Recent Research Results

During the past year, Henney has collaborated with J. Harvey in the development of new solar activity forecast maps. These data products, currently using KPVT synoptic data, include surface maps of magnetic field complexity, flux change and high-speed solar wind sources. Preliminary results were presented at the Spring 2001 SPD meeting in Boston. In addition, Henney created publicly available HTML pages for viewing the various daily forecast maps. Henney has continued collaboration with J. Harvey in the study of KPVT integrated full-disk synoptic signals for evidence of active solar longitudes. Additionally, he fine tuned a method to use signal phase information to measure the coherency of a signal. Preliminary results from this work were presented at the Spring 2001 SPD meeting in Boston and a manuscript describing the project is in press. Henney also continued collaboration with L. Bertello, F. Varadi and R. Ulrich of UCLA, along with R. Garcia of CEA/DSM/DAPNIA, in the analysis of low frequency p-modes using the GOLF and MDI velocity time series.

Future Research Plans

Henney will calibrate the solar activity forecasting parameters with past flare and CME events to eventually improve near real-time, observation-based models for the purpose of predicting solar activity, space weather and geomagnetic storms. After the SOLIS VSM instrument assemblage is completed, the VSM instrument calibration, vector analysis and cross-calibration of synoptic products with the KPVT will be his principal research tasks.

Service

As Data Scientist for the SOLIS project, Henney has developed C-based data reduction procedures for the Data Handling System (DHS) during the past year. He has continued to develop and maintain the data reduction procedures critical in the production of SOLIS-VSM 630 and 854 nm longitudinal data products in near real-time. This work included the development of procedures to access the DHS database for initialization of required processing parameters, along with updating previous data reduction procedures to use database I/O. Additionally, in collaboration with H. Jones, C. Keller, B. LaBonte, A. Lopez-Ariste, and H. Socas-Navarro, Henney compared five different Stokes inversion methods for the selection of the VSM "Quick-look" and final Stokes inversion procedures to be integrated into the SOLIS-VSM DHS. During the selection period, Henney created and maintained a HTML page with preliminary results for the active participants of the comparison group. This work was presented at the Spring 2002 SPD meeting in Albuquerque. He has also maintained the current Kitt Peak Vacuum Telescope (KPVT) synoptic data

pipeline and continued to modify the KPVT synoptic data reduction pipeline to process future VSM synoptic data as part of the SOLIS DHS. Additionally, Henney has continued collaboration with F. Hill and H. Jones in the development of the solar "active longitude" educational research project.

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 source of changes in the solar oscillations over the solar cycle. Using GONG and MDI data, Hill and co-workers found that the changes in frequency, amplitude, and lifetime of the modes could all be localized to the surface areas where magnetically active regions are located. In addition, there appears to be virtually no contribution to the shifts below the surface, suggesting that modification of the characteristics of the reflection at the upper turning point of the modes immediately below the photosphere may play a role in the variation. These new observations provide clues to the basic mechanism of solar activity. 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 has formed near the north solar pole. This counter cell appears to advance from and retreat back to the north pole with a two-year period, and can be considered to be the solar weather analog of the Earth's el Nino phenomenon.

Future Research Plans

Hill plans to analyze the ATST site survey data to investigate the environmental factors influencing daytime seeing at observing sites. He plans to use the GONG+ data and GONG++ processing system to produce a continual series of solar sub-surface weather maps. Hill will continue to follow the internal solar dynamics over the declining phase of the solar cycle.

Service

Hill is in charge of the ATST site survey, and chairs the ATST Site Survey Working Group. He 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, placing NSO data on-line and accessible over the Internet. This service is now available on the web at the URL http://www.nso.noao.edu/diglib. Hill is participating in the Virtual Solar Observatory (VSO) and European Grid of Solar Observations (EGSO) projects, and was a member of the NASA Virtual Observatory Science Definition Team. He is working on data archiving plans for SOLIS. Hill typically supervises several staff, currently three scientists. He is a member of the IRIS helioseismology network Scientific Committee, and the NSO Telescope Allocation Committee.

Rachel Howe, Assistant Scientist

Areas of Interest

Helioseismology, The Solar Activity Cycle, Peak Fitting

Recent Research Results

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

frequency shifts was presented at the SPD/AGU meeting in Spring 2001, and a paper on the subject was recently submitted to ApJ. With R. Komm, Howe also used the latitudinal inversion technique developed for the frequency shifts to localize changes in mode power and amplitude; the paper resulting from this work was published in ApJ in June 2002.

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 completed a major exercise in comparing GONG and MDI results from selected 3-month periods in an attempt to clarify the systematics involved in the analysis methods. This work was presented at the GONG '99 workshop, the SOHO10/GONG2000 workshop and the 2001 SPD meeting, and the part concerned with rotational splitting coefficients and rotation inversions was published in ApJ in March 2002. A further paper involving the central frequency differences is being prepared with S. Basu (Yale) as lead author.

During the summer of 2001, Howe worked with M. Roth (visitor/summer student from the Kiepenheuer Institute, Germany) and R. Komm on a numerical experiment to determine the detectability of large-scale flows in global helioseismic data. A paper was subsequently submitted to A&A and is currently in the final stages of the review process.

Howe continues to work on improved techniques for estimating mode parameters from GONG data in regimes where the standard GONG PEAKFIND algorithm is unsuitable. During the current year, Howe has worked on the calculation of the GONG leakage matrix, with a view to incorporating the matrix in peak fitting algorithms.

Future Research Plans

Howe intends to continue working on the above areas.

Service

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. In the past year, this has involved working with S. Kras and R. Komm on the re-analysis of all the GONG power spectra to date, using Multitaper Spectral Analysis. This has resulted in a noticeable improvement in the number of useful frequencies recovered.

Sankarasubramanian Kasiviwanathan, Research Associate

Areas of Interest:

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

Recent Research Results

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

Future Research Plans

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

Stephen L. Keil, NSO Director

Areas of Interest

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

Recent Research Results

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

Future Research Plans

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

<u>Service</u>

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

Christoph U. Keller, Associate Astronomer

Areas of Interest

Solar Magnetic Fields, High-Precision Imaging Polarimetry, Image Reconstruction Techniques, Active and Adaptive Optics, Telescope and Instrument Design

Recent Research Results

The collaboration with Rick Paxman and colleagues at Veridian has moved from active region studies to quiet network magnetic field studies. A recent movie of network magnetic fields at 0.2 arcsec resolution provides new insight into their dynamics. Collaboration with Jan Stenflo and his colleagues has moved from the visible to the UV. A successful run with the new UV ZIMPOL instrument shows many new featues in scattering polarization that await explanation. The new universal tracker at the McMath-Pierce telescope has allowed novel measurements of the CO emission above the limb using the FTS and has significantly improved the sensitivity of polarimetry at $12 \, \mu m$.

Future Research Plans

Apart from commissioning and analyzing the first science data from SOLIS, Keller will work on the design and development of the ATST. 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 in the infrared using the active and adaptive optics systems at the McMath-Pierce main telescope will allow him to use the full potential of this facility in the infrared.

Service

Keller is the telescope scientist for the McMath-Pierce telescope. He provides observing support at the McMath-Pierce and sometimes at the Sacramento Peak facilities. He is the lead scientist for the real-time software and hardware efforts for SOLIS and leads the vector spectromagnetograph effort. He is heavily engaged in various ATST activities and is the NSO representative on the Frequency Agile Solar Radiotelescope (FASR) project. Keller is a member of the local and joint-site project review committees.

Rudolf W. Komm, Assistant Scientist

Areas of Interest

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

Recent Research Results

Komm continues to perform research in helioseismology. With six 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, and studied the relation between p-mode energy and magnetic activity as a function of latitude and time. Komm is working on the temporal variation of angular momentum in the convection zone to study the dynamics of the solar interior. He is also working on advanced time-series analysis such as empirical mode decomposition and wavelet transform to evaluate their usefulness for helioseismology.

Future Research Plans

Komm will continue studies of the solar cycle variation of mode parameters of solar oscillations with the focus on the mode background amplitude and other indicators of mode physics. He will continue to study advanced time-series analysis techniques in order to evaluate their usefulness for helioseismology. With these techniques, Komm will study in greater detail the relation between p-mode energy and magnetic activity. He will continue to study the relation between solar oscillations and granulation (in collaboration with A. Nesis, Freiburg, Germany), as well as temporal variations of surface magnetic activity and large-scale flows (in collaboration with J. Javaraiah, Bangalore, India).

Service

Komm continues as a participant in Project ATSTRO.

John W. Leibacher, Astronomer

Areas of Interest

Helioseismology, Atmospheric Dynamics

Recent Research Results

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

Future Research Plans

Leibacher will be devoting the majority of his efforts to assuring GONG's technical and scientific success. He will also continue work on techniques of time series analysis and chromospheric oscillations. Ideas about

the observational signature of the convective excitation of p-mode oscillations will be pursued with data from GONG as well as the SOI/MDI instrument onboard the SoHO spacecraft.

Service

Leibacher serves as the Director of the Global Oscillation Network Group program. He serves on the editorial board of the journal Solar Physics, and chairs the AAS Solar Physics Division.

Matthew J. Penn, Associate Astronomer

Areas of Interest

Solar Atmosphere, Oscillations, Spectropolarimetry, Near-IR Instrumentation

Recent Research Results

Penn has published work done with CSUN undergraduate students in Solar Physics which included Evershed measurements, chromospheric line limb measurements, and sunspot magnetic field measurements at IR wavelengths. One student (J. Ceja) was selected to present his work in this project to Congress in the Papers on the Hill meeting at the Capital in Washington DC.

Penn has also submitted a paper to Nature with J. Allen concerning new results from the spectro-polarimetric observations of the Mercury sodium atmosphere. New measurements of eruptive prominences with the CSUN-NSO IR camera taken at the Kitt Peak McMath-Pierce telescope were presented at the 2002 AAS/SPD meeting.

Future Research Plans

Penn will run a two-month campaign at the San Fernando Observatory making active region vector magnetograms at the 1565 nm Fe I line in collaboration with TRACE observing. A collaborative run with VLA solar observations is also planned. New observations of He I 1083 nm line asymmetry are also planned.

<u>Service</u>

Penn has been in charge of the ATST Coronal Workgroup. A draft document has been developed describing science goals and requirements for the ATST. Penn is also heading the ATST Nighttime Working Group, and initial discussions in this group has identified a list of night time uses for the ATST. Penn is working closely with U. of Hawaii/IfA and HAO staff in the infrared spectropolarimetric instrument development for ATST. Finally, Penn is working on the NSO Array Camera (NAC) project to develop the initial science InSb camera system for use in the 1-5 micron range. Penn's future service plans include promoting NSO user interest in the NAC system during 2003 and finishing the activities of the ATST Coronal and Nighttime Working Groups. He will be involved in a NASA review of instrument proposals for the Solar Dynamics Observatory and will seek collaborative science observations between ATST and SDO.

Alexei A. Pevtsov, Associate Astronomer

Areas of Interest

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

Recent Research Results

A. Pevtsov worked with researchers from other institutions on several studies including cyclic variation of the number of X-ray bright points and photospheric bipoles, helicity of large-scale magnetic field, a correlation between X-ray luminosity and magnetic flux, properties of magnetic clouds resulting from eruption of sigmoids, correlation between active region filaments and X-ray sigmoids, properties of X-

ray sigmoids, magnetic twist and writhe of active regions, and statistical properties of superpenumbral filaments.

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

In co-authorship with researchers from Montana State U., UC-Berkeley, Rice U. and Lockheed Martin Advanced Technology Center, it has been discovered that X-ray luminosity and unsigned magnetic flux for several different objects (quiet Sun, X-ray bright points, solar active regions, Sun-as-whole, K, G, and M dwarfs and T-tauri stars) exhibit a close-to-linear correlation over 12 orders of magnitude. The simple, linear relationship suggests a common heating mechanism on the Sun and other stars, although the level of scatter about that relationship suggests that other magnetic parameters, such as the detailed morphology, also play an important role. The nearly linear relationship also suggests that X-rays will provide a useful proxy for magnetic flux estimates on stars when magnetic data are unavailable.

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

Yohkoh soft X-ray telescope data and H-alpha full disk (NSO/SP) observations were used to establish a close spatial correlation between chromospheric filaments and coronal sigmoids. Detailed study of the evolution of chromospheric filaments and coronal sigmoids in 6 active regions associated with CMEs showed that X-ray sigmoids may erupt and produce CMEs even without complete eruption of underlying filament. The results of this study seem to support classical two-ribbon flare model.

Study of magnetic twist and writhe of active regions deals with bipolar regions in which the main (sunspot) polarities rotate around each other during several solar rotations. It has been shown that this rotation is not due to solar differential rotation, but reflects emergence of distorted magnetic flux tube. In approximately one-third of all cases the flux tube deformation may be the result of kink-instability. The rest may be explained by the action of the Coriolis force and/or large-scale plasma rotational motions on the flux tube rising through the convection zone.

Future Research Plans

A. Pevtsov will continue to study the properties of X-ray bright points and associated photospheric bipoles,

A. Pevtsov will continue to study the properties of X-ray bright points and associated photospheric bipoles, the role of magnetic field in coronal heating, and the relationship between solar drivers and geomagnetic storms.

Other research plans include the study of tilt-twist correlation using ARs magnetic fields, evolution of helicity during magnetic flux emergence and the evolution of delta-spots.

Service

Pevtsov has supervised the NSO/SP technical librarian, served as NSO/SP colloquium Chair, reviewed NSO/SP observational proposals, and participated in the SP/TAC meetings. He also participated in the ATST ASWG meetings. He supervised two NSO summer students and one teacher-participant of the

NSO's RET program. Together with H. Uitenbroek, he organized the 21st NSO/SP Workshop and served as editor for the workshop proceedings. During FY 2002, he served as a reviewer for four professional journals (Solar Physics, the Astrophysical Journal, the Astronomy and Astrophysics, and Journal of Geophysical Research). He also reviewed scientific proposals for NSF and NASA. He conducted several public tours at the Sacramento Peak observatory, and gave presentations for students at Cloudcroft Middle (8th grade physics classes) and Tularosa Elementary Schools (Career Day). He also gave a public lecture in New Mexico Museum of Space History in Alamogordo, NM.

Thomas R. Rimmele, Astronomer

Areas of Interest

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

Recent Research Results

Rimmele has published results from high-resolution observations of umbral fine structure. He found evidence for oscillatory magnetoconvection in a sunspot light bridge. Oscillatory convection in strong magnetic fields has been predicted by theoretical models but never observed before. Rimmele collaborates with P. Goode and L. Strous (NJIT), and Tuck Stebbins (JILA), studying the excitation of solar oscillations. Their observations show that acoustic power is generated in intergranular lanes and give a detailed description of the mechanism responsible for the conversion of convective energy into acoustic energy. They are also able to show that the acoustic energy is fed into the resonance modes of the Sun.

Future Research Plans

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

<u>Service</u>

In an ongoing effort, Rimmele is working with R. Radick (NSO/SP/AFRL) and R. Dunn (NSO/SP) on improving optical performance of the Dunn Solar Telescope (DST). Rimmele is developing narrow-band filter capabilities for the DST using Fabry-Perots and participates in an ongoing effort to upgrade CCD detectors at NSO/SP. Rimmele is Project Scientist for the Advanced Technology Solar Telescope Project, principal investigator of the NSF/MRI-funded Solar Adaptive Optics Program, and serves as Chair of the Sac Peak site Project Review Committee (PRC).

Clifford Toner, Assistant Scientist

Areas of Interest

Global and Local Helioseismology, Image Restoration, Data Analysis Techniques

Recent Research Results

Toner has devoted most of his time to the support of the GONG+ upgrade. He ran comparisons been GONG+ and MDI data, showing that there is a high degree of correlation (correlation coefficient > 0.85) up to spherical harmonic degree 1 of ~600. Above this value terrestrial seeing progressively degrades the GONG+ data. However, there is significant signal up to 1-values of ~1000. This is sufficiently high for local helioseismology. When the first GONG+ instrument was deployed at Big Bear, Toner used simultaneous data obtained by the GONG+ proto-type instrument in Tucson to confirm that the high-resolution data can be successfully merged, and that it will provide higher quality spectra than merged GONG Classic data. Toner has developed an algorithm which will allow the merging of GONG+ data with GONG Classic data, so that it will be possible to

maintain a high duty cycle during the period of time when the "Classic" network is being replaced with "Plus" network. Toner has also improved the determination of the relative angular orientation of GONG+ images to ~0.002 degrees and has developed a method for measuring periodic errors which are introduced by the gears which drive the camera rotator mechanism at each GONG instrument.

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

Future Research Plans

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

<u>Service</u>

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

Han Uitenbroek, Associate Astronomer

Areas of Interest

Radiative Transfer Modeling and Atmospheric Structure and Dynamics

Recent Research Results

H. Uitenbroek has been improving and expanding his multi-dimensional numerical radiative transfer code. The performance of the numerical code under partial frequency redistribution (PRD), which is needed to model and analyze strongly scattering lines in the solar spectrum, is now on par with that under complete frequency redistribution (CRD), which is more commonly used. The code is publicly available and several people in the community have requested a copy. The most recent addition to the code is the capability to perform angledependent PRD calculations. This is needed when inhomogenities and/or macroscopic velocity fields increase the anisotropy of the radiation field. With this new version of the code, Uitenbroek has investigated the influence of PRD on the radiative cooling in the CaII H and K lines. These play an important role in the energy balance of the solar chromosphere. The detailed structure in the recent dynamical models of the solar chromosphere by Carlsson and Stein, for instance, depends in large part on balance between mechanical shockwave heating and the radiative cooling in the calcium lines. The calculations presented by Uitenbroek show that the radiative cooling estimates can be considerably in error if CRD is used for the calcium lines, as is done currently by Carlsson and Stein, instead of the more physically realistic PRD approach. Another addition to the code is the capability to perform non-LTE calculations of all four Stokes components of the radiation field in the presence of magnetic fields. With K.S. Balasubramaniam at Sac Peak, Uitenbroek has obtained spatially and temporally resolved observations of the Ca II 854.2 nm line. The full Stokes capability of the transfer code will be employed to analyze these observations, which hold the potential to improve the estimate of chromospheric magnetic field strengths. Uitenbroek has also extended his numerical code to include the effects of PRD with cross redistribution (XRD), in which photons can scatter coherently from one line to the other. Calculations have shown that XRD is important for the formation of the diagnostically important O I triplet lines at 130 nm.

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. The numerical Stokes code will be used to investigate the viability of H polarimetry to measure chromospheric magnetic fields in addition to the use of the Ca II 854.2 nm line.

<u>Service</u> Uitenbroek is PI	of the infrared came	era effort at the	Dunn Telescope	in Sac Peak. He	also oversees the
science exhibit a	at the Sunspot Visito each programs such	or Centre and wo	rks with K.S Ba		
educational outr	cacii programs sucii	as KET/KEO at	id TERDSE.		

APPENDIX E: DEFERRED MAINTENANCE FY 2003

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 2003 facilities maintenance projects at each site are described below.

Sacramento Peak

The FY 2003 NSO/SP budget includes approximately \$20K for items above the normal reactive maintenance program and approximately \$20K from housing revenues above the normal maintenance for housing. We also expect to have carryover funds of approximately \$50K. The housing revenue funds will be used to upgrade permanent and visitor housing including upgrading a visitor quarters for compliance with the American's with Disabilities Act. In addition, the Long-Range Plan lists as other maintenance tasks the demolishing of the Cloudcroft facility/RCA building. This is an item that has been carried forward for several years. Although important, funding availability and priorities have not allowed completion of this item. We will continue to monitor this situation and will accomplish this task whenever possible.

Table E-1. NSO-Sac Peak Summary of FY 2003 Projects(Dollars in Thousands)

Project	Est Cost
Water Tank Cathodic Protection	10
Main Lab Improvements	25
Commercial/Telescope Painting	10
Housing Upgrades	20
Cloudcroft Facility/RCA Building Demolishing	50
TOTAL	\$ 115

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.

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

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

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

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

Kitt Peak

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

Table E-2. NSO-Kitt Peak Summary of FY 2002 Projects

Project Est. Cost

McMath-Pierce electrical upgrade \$30

McMath-Pierce painting 15

Re-roofing and sealing 5

McMath-Pierce fall protection 5

TOTAL \$50

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

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

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

APPENDIX F: TELESCOPE USAGE STATISTICS FY 2002

National Solar Observatory FY 2002 Telescope Usage Statistics

In the 12 months ending 30 September 2002, 82 observing programs, six of which were thesis programs, were carried out at NSO. Associated with these programs were 108 scientists from 57 US and foreign institutions.

NSO Observing Programs by Ty (US vs Foreign)	/pe	
12 Months Ending 09/01	Nbr	% Total
Programs (US)	64	78%
Programs (non-US)	12	15%
Thesis (US)	3	4%
Thesis (non-US)	3	4%
Total Number of Unique Science Projects*	82	100%

^{*}Includes observing programs conducted by NSO/NOAO staff scientists.

Users of NSO Facilities by Category							
Visitors				AURA Staff			
US	Non-US	Total	% Total				
65	23	88	84%	20			
5	4	9	9%	-			
6	0	6	6%	-			
0	2	2	2%	11			
76	29	105	100%	31			
	US 65 5 6 0	US Non-US 65 23 5 4 6 0 0 2	US Non-US Total 65 23 88 5 4 9 6 0 6 0 2 2	Visitors US Non-US Total % Total 65 23 88 84% 5 4 9 9% 6 0 6 6% 0 2 2 2%			

Number of Users by Nationality				
Canada	4	Japan	3	
China	1	Mexico	1	
France	4	Switzerland	3	
Germany	4	United Kingdom	1	
Greece	2	United States	107	
Italy	6			

Institutions Represented by Visiting Users**					
	US	Non-US	Total	% Total	
Academic	22	13	35	61%	
Non-Academic	15	7	22	39%	
Total Academic & Non-Academic	37	20	57	100%	

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

Institutions Represented by Visiting Users

US Institutions (37):

Alfred University

American Institute of Physics

California State University, Los Angeles California State University, Northridge Cambridge Research & Instrumentation Carnegie Institution of Washington

Catholic University

College of William and Mary Colorado Research Associates

Connecticut College Dickinson College East Carolina University Edinboro University

Harvard-Smithsonian Center for Astrophysics

Helio Research

High Altitude Observatory, NCAR

Jet Propulsion Laboratory McDonald Observatory Montana State University

NASA Goddard Space Flight Center

NASA Langley Research Center NASA Marshall Space Flight Center

National Oceanic and Atmospheric Administration

Naval Research Laboratory

New Jersey Institute of Technology Prairie View A & M University Solar Physics Research Corp.

Southern Illinois University, Edwardsville

Southwest Research Institute Space Telescope Science Institute

St. Cloud State University University of Arizona

University of Central Florida

University of Hawaii, Institute for Astronomy

University of New Mexico

University of Wisconsin, Madison

University of Virginia

U.S. Air Force Research Laboratory, Sac Peak U.S. Air Force Research Laboratory, Petersen AFB

Yale University

Foreign Institutions (20):

Chinese Academy of Sciences

ETH Zürich

Imperial College of Science & Technology Institut d'Astrophysique de Paris (CNRS) Kiepenheuer Institut für Sonnenphysik

National Observatory of Athens

Observatoire de Paris

Observatoire de Pic-du-Midi Osservatorio Astrofísico di Arcetri

Osservatorio Astronomico di Capodimonte

Thueringer Landessternwarte Tautenberg

Universidad de Monterrey, Mexico Universita "La Sapienza" Rome

University of Calgary University of Florence University of Naples

Université Paris Sud Batisments

University of Patras University of Rome University of Tokyo University of Waterloo

APPENDIX G: NSO MANAGEMENT

Stephen Keil NSO Director; ATST Project PI

Mark Giampapa Deputy Director for Tucson Operations; SOLIS Project PI

Rex Hunter Site Manager, Sacramento Peak

Thomas Rimmele ATST Project Scientist; Solar Adaptive Optics Program PI

Jim Oschmann Manager, ATST Project

Stephen Hegwer Manager, Sac Peak Technical Programs

Jeremy Wagner Manager, SOLIS Project; Deputy Project Manager, ATST

John Leibacher Project Director, GONG
Pat Eliason Manager, GONG Project

NOAO Managers Who Provide NSO Program Support

Larry Daggert Manager, Engineering and Technical Services (ETS)
Steve Grandi Manager, Computer Infrastructure Services (CIS)
Larry Klose Manager, Central Administrative Services (CAS)

Sandra Abbey Human Resources Manager

Patrick Phelan Business Manager

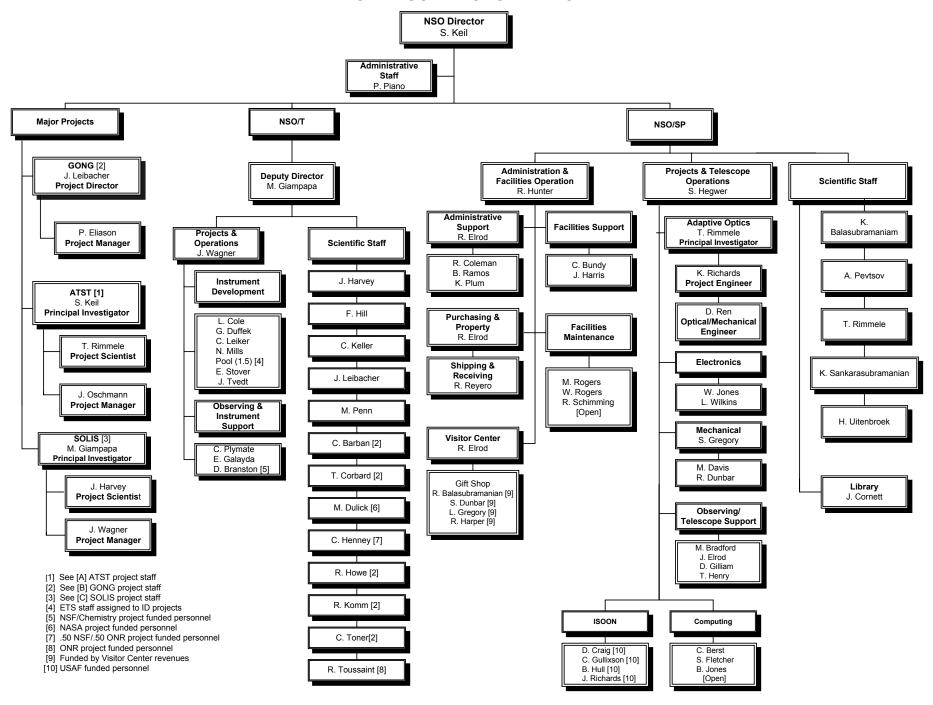
James Tracy Controller

Chris Richardson Assistant Controller

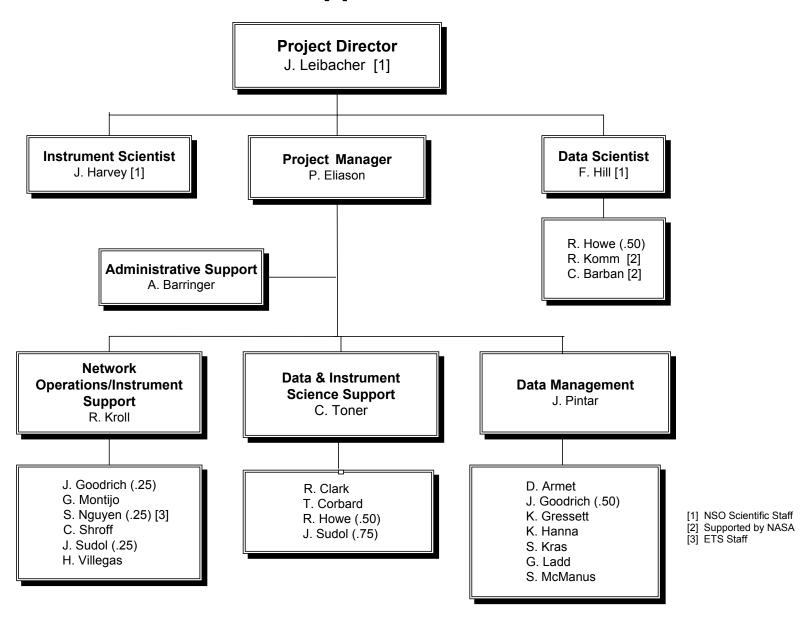
John Dunlop Manager, Central Facilities Operations & Kitt Peak Facilities

Doug Isbell Manager, Public Affairs and Educational Outreach

NATIONAL SOLAR OBSERVATORY

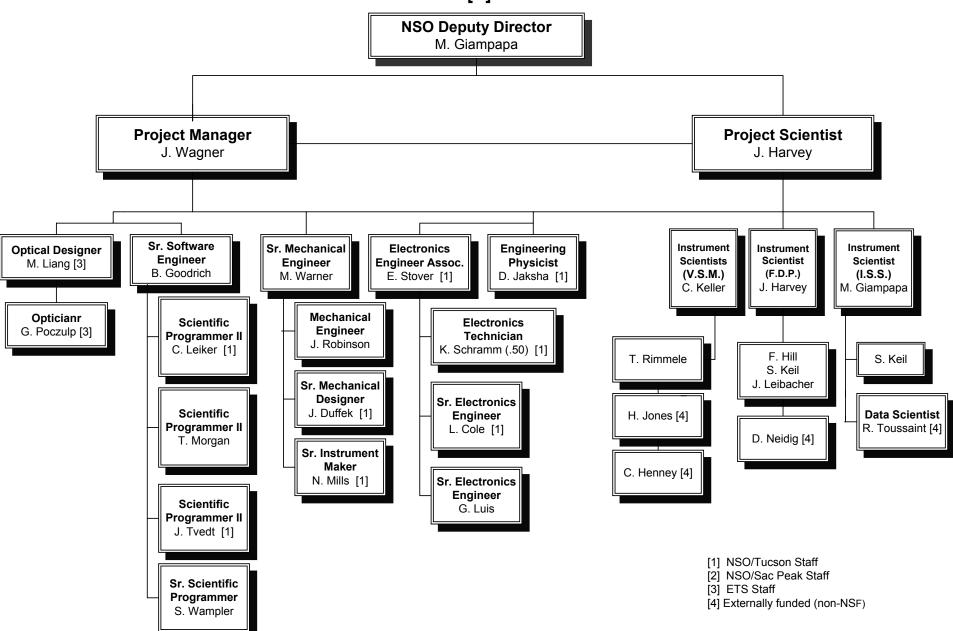


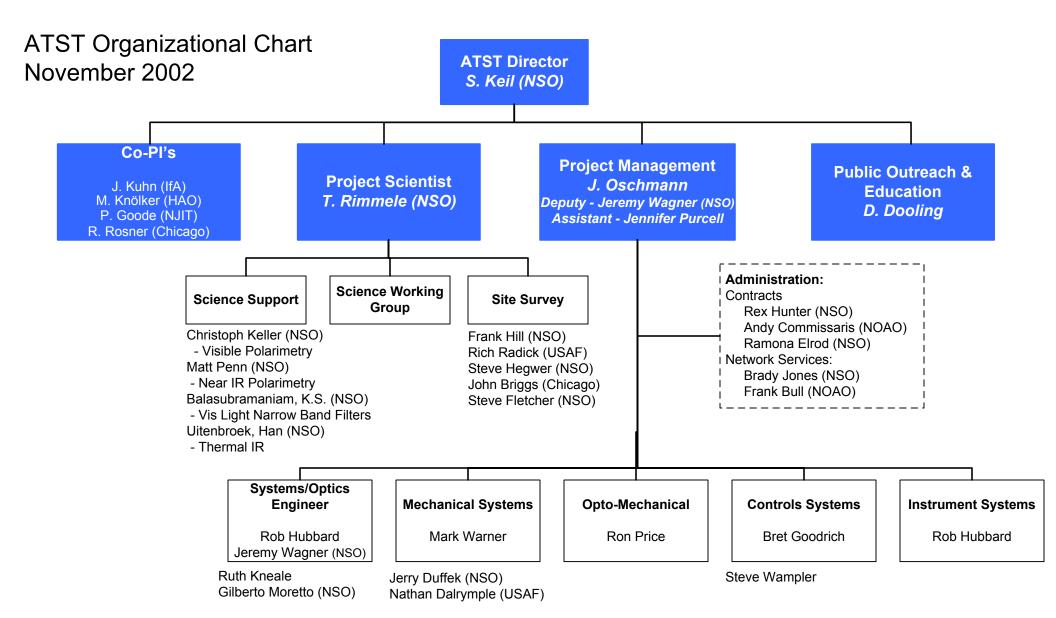
NSO GLOBAL OSCILLATION NETWORK GROUP [B]



SYNOPTIC OPTICAL LONG-TERM INVESTIGATIONS OF THE SUN SOLIS PROJECT

[C]





APPENDIX I: ACRONYM GLOSSARY

AASC Astronomy and Astrophysics Survey Committee

AAS American Astronomical Society
AFRL Air Force Research Laboratory
AGU American Geophysical Union

AO Adaptive Optics

AO76 Adaptive Optics system with 76 degrees of freedom

ARs Active Regions

ASP Advanced Stokes Polarimeter ASWG ATST Science Working Group

ATST Advanced Technology Solar Telescope

AURA Association of Universities for Research in Astronomy, Inc.

BBSO Big Bear Solar Observatory
CCD Charged Couple Device

CD-ROM Compact Disk – Read Only Memory

CoDR Concept Design Review

CRD Complete Frequency Redistribution
CSUN California State University, Northridge

DHS Data Handling System

DMAC Data Management and Analysis Center

DST Dunn Solar Telescope

EPO Educational and Public Outreach

ESF Evans Solar Facility

ETH-Zürich Eidgenössische Technische Hochschule- Zürich

FASR Frequency Agile Solar Radiotelescope

FDP Full Disk Patrol FP Fabry-Perot

FTS Fourier Transform Spectrometer

FY Fiscal Year GB Giga Bytes

GONG Global Oscillation Network Group
GOLF Global Oscillations at Low Frequencies

GSFC Goddard Space Flight Center HAO High Altitude Observatory

HESSI High Energy Solar Spectroscopic Imager

HT Hilltop Telescope

IAC Instituto de Astrofisica de Canarias

ICD Interface Control Document

IR Infrared

ISOON Improved Solar Observing Optical Network

ISS Integrated Sunlight Spectrometer
KIS Kiepenheuer Institute for Solar Physics

KPNO Kitt Peak National Observatory
KPVT Kitt Peak Vacuum Telescope

LAN Local Area Network

LTE Local Thermal Equilibrium
MDI Michelson Doppler Imager
MHD Magnetohydrodynamic

APPENDIX I: ACRONYM GLOSSARY

MO&DA Mission Operations & Data Analysis (NASA)

MRI Major Research Instrumentation (NSF)

NAS National Academy of Sciences

NASA National Aeronautics and Space Administration

NJIT New Jersey Institute of Technology

NOAA National Oceanic and Atmospheric Administration

NOAO National Optical Astronomy Observatory

NOAO/ETS National Optical Astronomy Observatory/Engineering and Technical Services

NRC National Research Council
NSF National Science Foundation

NSF/AST National Science Foundation, Division of Astronomical Sciences NSF/ATM National Science Foundation, Division of Atmospheric Sciences

NSO National Solar Observatory

NSO/SP National Solar Observatory Sacramento Peak

NSO/T National Solar Observatory Tucson

OCS Observing Control System

PAEO Public Affairs and Educational Outreach

PCA Principal Component Analysis
PRD Partial Frequency Redistribution
PSPT Precision Solar Photometric Telescope
RBSE Research-Based Science Education
RET Research Experiences for Teachers
REU Research Experiences for Undergraduates

RISE Radiative Inputs of the Sun to Earth

SCOPE Southwest Consortium of Observatories for Public Education

S-DIMM Solar Dual Image Motion Monitors SOHO Solar and Heliospheric Observatory

SOI/MDI Solar Oscillations Investigations/Michelson Doppler Imager (SOHO)

SOLIS Synoptic Optical Long-term Investigations of the Sun

SPD Solar Physics Division
SRA Summer Research Assistant
SRD Science Requirements Document

STEREO Solar Terrestrial RElational Observatory (2 spacecraft)

TB Tera Bytes

TCS Telescope Control System

TRACE Transition Region and Coronal Explorer UCSD University of California, San Diego

UV Ultraviolet

VMG Vector Magnetograph

VSM Vector Spectromagnetograph VSO Virtual Solar Observatory WBS Work Breakdown Structure

WWW World Wide Web
XBP X-ray Bright Points
XRD Cross Redistribution

Yohkoh "Sunbeam," Satellite project of the Japanese Institute of Space and Astronautical Sciences

ZIMPOL Zürich IMaging POLarimeter