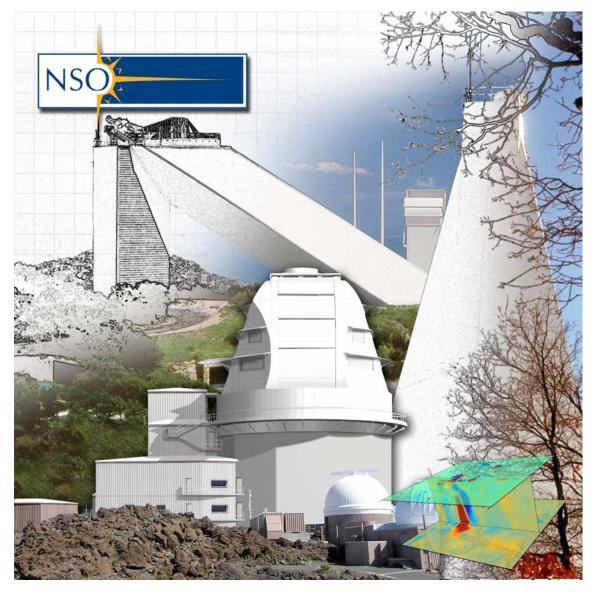
ANNUAL REPORT OF THE NATIONAL SOLAR OBSERVATORY FY 2005



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1 EXECUTIVE SUMMARY

This report summarizes scientific, operational, and programmatic activities at the National Solar Observatory (NSO) for the period 01 October 2004 to 30 September 2005.

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

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

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

The NSO reached several key milestones in its multi-year program to renew national ground-based solar observing facilities. Among these milestones were the highly favorable scientific, technical and cost review of the construction phase proposal for the 4-meter Advanced Technology Solar Telescope (ATST); initial operations of the Vector Spectromagnetograph (VSM) and commissioning operations of the Integrated Sunlight Spectrometer (ISS) of the new Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility on top of the Kitt Peak SOLIS Tower (KPST), including presentations of SOLIS VSM data at the New Orleans AAS Solar Physics Division meeting by members of the community; conduct of additional Multi-Conjugate Adaptive Optics (MCAO) observing runs at the Dunn Solar Telescope (DST); scientific operations of the upgraded Global Oscillation Network Group (GONG) facility for local helioseismology; upgrades of the Advanced Stokes Polarimeter (ASP) that include: completion of the integration of the camera for the Diffraction-Limited Stokes Polarimeter (DLSP) with other instrument control computer (ICC) cameras, including the commencement of user observing runs with the DLSP, and significant progress in the development of a Spectro-Polarimeter for Infrared and Optical Regions (SPINOR); delivery of, and initial science observations with, the NSO Array Camera (NAC) for highsensitivity infrared observations at the McMath-Pierce; significant progress in the development of specifications for a Telescope Control System (TCS) upgrade at the McMath-Pierce Solar Telescope; and release of V1.0 of the Virtual Solar Observatory (VSO) to the community, including the subsequent release of both a shopping cart utility and a movie tool.

The major components of the NSO long-range plan include: continuing to lead the development of the 4-m ATST; developing adaptive optics (AO) systems that can fully correct large-aperture solar telescopes; deploying and operating the instruments comprising SOLIS; operating GONG in its new high-resolution

mode; and collaborating with the community in the establishment of the Virtual Solar Observatory for the archiving and dissemination of solar data. These new and planned instruments and facilities, as the principal foundations of the NSO along with its scientific staff, are key elements in a vigorous program of scientific leadership by the United States in ground-based solar physics.

The NSO encourages broad community involvement in its programs through partnerships to build instruments, develop new facilities and to conduct scientific investigations. Agreements have been established with the High Altitude Observatory (HAO), the New Jersey Institute of Technology (NJIT)/Big Bear Solar Observatory (BBSO), the University of Hawaii, and the University of Chicago for their efforts in the ATST collaboration.

NSO and HAO have completed 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). Both institutions have started another collaborative effort to develop SPINOR, which will augment capabilities for research spectro-polarimetry at the DST.

The NSO is in discussion with potential international partners that are interested in the establishment and operation of a SOLIS/VSM global network. The NSO works closely with the Air Force, NASA, and NOAO to provide critical synoptic observations that, in addition to producing noteworthy science, also support space weather monitoring and prediction as well as space and other ground-based observations.

2 PROGRESS TOWARD THE FUTURE

2.1 Advanced Technology Solar Telescope (ATST)

The FY 2004 annual report described the progress of a community-wide project to develop the Advanced Technology Solar Telescope—the next generation, facility-class telescope to advance high-resolution solar physics and the measurement of solar magnetic fields. What follows is an update of the ongoing ATST design effort as well as the construction phase proposal review.

With its 4-meter aperture and integrated adaptive optics (AO), the ATST will resolve areas on the Sun over an order of magnitude smaller than current meter-class solar telescopes. Its high photon flux and broad spectral coverage will allow it to make sensitive magnetic field observations at heights from the photosphere into the corona.

Observations have established that the photospheric magnetic field is organized in small fibrils, or flux tubes, with sizes below current resolution limits. Theory and models predict that these fibrils have scales of just a few tens of kilometers (\leq 30 km) and that they play fundamental roles in solar dynamo processes, atmospheric heating, and solar activity. Resolving and measuring the properties of the magnetic field at its fundamental scale is thus a primary goal for the ATST. A complete description of science goals, and project information, can be found at <u>http://atst.nso.edu</u>.

2.1.1 ATST Science Working Group (SWG)

Current membership of the Science Working Group can be found at <u>http://atst.nso.edu/-swg/members.html</u>. The SWG met during the past year to quantify many of the observing capabilities specified for the ATST to meet its science goals. Most significantly, the SWG met in October 2004 to review the Site Survey Working Group (SSWG) final report and to recommend the primary and alternate sites for the ATST.

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

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

2.1.2 ATST Project Organization

NSO Director Steve Keil is the ATST Project Director. The science team reports to the Project Scientist Thomas Rimmele, and the engineering team reports to Project Manager Jeremy Wagner.

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

- High Altitude Observatory (Visible Light Spectro-Polarimeter Design; Near IR Spectro-Polarimeter Contributions).
- University of Hawai'i (Sky Brightness Monitor and Dust Monitor; Near Infrared Spectro-Polarimeter Design (Lead); Site Survey Operations on Haleakalā 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).

The project continues to seek additional participation by international collaborators. A meeting to develop the formation of an international ATST partnership was held in November 2005. A structure for the organization was agreed upon by representatives from several countries, including the US, Germany, France, Italy, Spain, the United Kingdom, the Netherlands, Sweden, and Norway. NSO is taking the lead in sending out formal invitations to join the organization.

2.1.3 Construction Phase Proposal Review

Since its submission, the ATST construction phase proposal has undergone both write-in reviews and a face-to-face panel review at the NSF. Both reviews were extremely positive and have recommended that NSF fund the construction of the ATST. In March 2005, the NSF held an ATST construction proposal cost review in Tucson. In late September 2005, the project was advised that the NSF Director had elevated the ATST to a readiness stage (Major Research Equipment and Facilities Construction (MREFC) project, a major milestone in the review process. One of the next steps in the review process is to present the project to the National Science Board for consideration for inclusion in the MREFC funding line for FY 2008.

2.1.4 Design Progress

Design activities during the past year were focused on completing follow-up activities from the Conceptual Design Review (CoDR) committee recommendations, the Enclosure review held in October 2004, the M1 Assembly review held in December 2004, and the Telescope Control System (TCS) workshop held in March 2005, as well as refining engineering flow-down of requirements, performance modeling, and related activities leading to a series of System Design Reviews (SDRs) beginning in October of 2005.

2.1.4.1 Optical Design

The ATST optical design was frozen during the last year. At the top end of the optical train, the size, location, and optical prescription of the first six mirrors were frozen. These include the off-axis primary and secondary mirrors (M1 and M2), a flat fold mirror (M3), an off-axis aspheric transfer mirror (M4), the

nominally flat deformable mirror (M5) and the fast tip-tilt flat (M6). These six mirrors combine to form a horizontal relay image located just below the telescope along the azimuth axis.

We have also frozen the optical prescription for three alternative Nasmyth mirrors: M3N is a flat that is substituted for M3 during Nasmyth operations; M4N and M5N are off-axis aspheres that combine to transfer the f/13 Gregorian image to the Nasmyth focal plane, also operating at f/13.

A more cost-effective way to form the final image down in the coudé room was also investigated. Because of a requirement for an MCAO upgrade path, two additional powered folding mirrors in the baseline plan (M7 and M8) are located at suitable conjugate heights in the earth atmosphere, followed by a final flat pupil-steering mirror (M9) that renders our beam collimated and horizontal in the coudé room. Our baseline optical design calls for the two MCAO conjugate mirrors to be off-axis aspheres. We investigated alternatives that allow these mirrors to become spherical while preserving diffraction-limited performance with a low-order programmable deformable mirror. A number of other options, including using the M5, the main high-order deformable mirror, or one of the spheres (likely M8) to accomplish the necessary correction were also investigated.

We have also refined a detailed strategy for maintaining quasi-static alignment (QSA) of the telescope. A contracted study performed by Optical Research Associates in Tucson and Pasadena demonstrated that misalignment of optical components (due primarily to the slow flexure of the optical support structure holding M1 and M2 as the gravity vector changes) can be corrected by shifting M2 on its hexapod mount while maintaining optical bore-site alignment with the M3 and M6 flats. Three sensors sampling the wavefront at off-axis field points, working in conjunction with the active optics (aO) or adaptive optics (AO) wavefront sensors sampling on axis, give sufficient information to move these mirrors to optimum positions during operations. The update rates will be similar to or slower than that required for the M1 aO system.

2.1.4.2 Enclosure

Overall cost reduction of the thermal systems has been a focus for the enclosure design effort. The final report on the enclosure thermal system design delivered from M3 Engineering in March 2005 detailed a baseline system with an estimated construction and operating cost that was more than the enclosure budget allocations in the construction and operations budgets. To bring the overall cost of the thermal system into line, a multifaceted approach has been undertaken. This has included reducing the exposed surface area that receive direct and indirect solar load, minimizing the overall thermal load per unit area, and finding cost reductions (both capital and operational) in the design of the thermal systems.

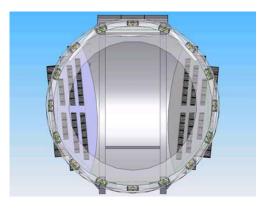


Figure 1. A plan (top-down) view of the enclosure carousel. The relatively minor 5-degree taper along the sides of the dome results in a significant increase in shaded surface area. It also provides room for ~11% larger vent gates for increased passive ventilation.

Key to the consideration of any optimization or compromise of the baseline thermal system is an understanding of the specific site conditions that will be encountered at Haleakalā. This understanding is also essential in order to set up boundary conditions and use cases for thermal, computational fluid dynamics (CFD), and multi-physics analyses of various configurations in these "what-if" studies. Statistical

analyses of site seeing and weather data show that the majority of excellent seeing conditions ($R_0 > 12cm$) occur early in the day, mostly during periods of moderate wind (~5 m/sec) that come generally from the northeast. Additionally, some of the most excellent seeing conditions occur during winter mornings with moderate wind from the northwest. There is also a negligible amount of excellent seeing conditions which occur on no-wind and/or low-wind mornings.

The enclosure carousel exterior will be cooled with chilled water/glycol solution circulated through plate coil heat exchangers that are mounted to the exterior of the carousel. Strategies for maximizing fully shaded areas have the potential to minimize plate coil coverage requirements. For example, adding a 5-degree taper along the sides of the dome resulted in a significant amount of surface area remaining fully shaded as the sun is tracked during the day. It also provided space for approximately 11% larger ventilation gates. Another benefit to the taper is that it leaves the geometry more octagonal in shape, with the support points aligning closely with bogie locations.



Figure 2. An artist's rendering of ATST at the primary site on Haleakala. Elevation view is from the north. Note the white concrete apron located on the eastern (left) side of the facility that is used to reduce radiated thermal loading from the ground.

While the early MuSES thermal model results are promising, multi-physics modeling efforts using STAR-CD CFD software are underway to verify that the strategic placement of cooling systems does not compromise excellent seeing conditions. The trade of cooling coverage against cost must be done very carefully, leaving easy upgrade paths in case future operational experience reveals different results than model predictions.

To significantly lower the cooling costs per unit area, a less expensive type of plate coil heat exchangers has been selected. This style actually has an advantage in that more of the surface area is in actual contact with the glycol solution, leaving a more even temperature gradient across each plate coil unit. Another examined method to lower cooling costs was the installation of an ice storage system that may allow substantial operational savings. This type of system may be eligible for the Customized Incentives available through Maui Electric's Energy\$olutionsSM for Business program, which could help offset some of the capital costs. This avenue of potential savings in operational costs is being pursued with Maui Electric Company.

Earlier thermal modeling by Nathan Dalrymple (USAF/AFRL) showed promising results for using different ground treatments to reduce the overall thermal load on the enclosure. This work suggested white-painted concrete to be the best ground treatment for use on Haleakalā. In a follow-on study, the load reduction for varying sizes of this concrete apron was explored. In that study, it was shown that a 10-meter-wide white concrete apron surrounding the enclosure resulted in a 30% reduction of overall thermal load on the enclosure as a whole, and a 40% reduction in thermal load for the eastern side of the lower enclosure. Properly designed, the apron can also serve to catch rainwater as well as provide containment for any leaks in the hydronic cooling system.

2.1.4.3 Support and Operations (S&O) Building

Refinements to the S&O building design in the past year have been driven by the establishment of the telescope height, the optimal configuration and orientation of the structures based on Haleakalā site specific seeing and wind direction, and a more detailed consideration of a coating facility

Heeding the advice of the SWG at the time Haleakalā was selected, the above-ground height of the telescope was raised from 24 meters to 28 meters, resulting in a corresponding height increase in the level of the coudé platform and the adjacent control room floor in the attached support building. This created enough vertical volume in the S&O building to incorporate an intermediate "mezzanine" level for support space below the coudé/control room level, as well as allowing the overall building footprint to be reduced. The size of the attached support building was further reduced by deleting an on-site machine shop from the new building and accommodating this need with a planned expansion of the existing shop in the University of Hawai'i, Institute for Astronomy Mees facility.

With guidance from coating specialist Gary Poczulp (NOAO), our team took a closer look at the space implications of coating the primary mirror within our own facility. Interior building space had been allocated in earlier designs for a coating chamber, an overhead crane and a washing/stripping area. However, realistic assessment of the required maneuvering of the 4.2-meter off-axis primary mirror (i.e., without the typical central hole found in on-axis telescope designs), as well as its cell, cart, lifting fixture, wash rack, and support equipment, showed a clear need for slightly more floor space than allowed in the high-bay base level area. We remain optimistic that a proposed new Air Force coating facility at the Advanced Electro Optical System (AEOS) facility on Haleakalā will be available to recoat the ATST primary mirror. Until we are certain of that, however, our baseline facility design must continue to incorporate full M1 recoating capabilities.

Based on CFD analysis, the platform lift to transport the M1 assembly between the telescope and base levels was also refined, including a lift-up roof to minimize the height of the building and the resultant thermal turbulence near the aperture. In a similar regard, the optimal orientation of the entire S&O building was

concluded to be due west of the telescope enclosure. This was determined by an analysis of the predominant weather conditions on Haleakalā, the wind induced air flow pattern around the proposed structures, and beneficial shading of the support building by the enclosure. A detached utility building, which houses the backup generator, a large chiller, exhaust fans, and ice storage tanks, was sited to the west of ATST and north of Mees. This utility building will be connected to the S&O building by an underground utility/ventilation shaft. We have also studied the extent of noise abatement that will be necessary for the utility building and the equipment inside.

In parallel, thermal control concepts for the primary mirror and other optics have evolved, with concentration on the primary and secondary mirrors. The thermal models have been updated to include seeing effects based upon work by Nathan Dalrymple. These models were also extended to apply to mount and dome shell seeing. The latter are the primary technical concerns of efforts leading to the System Design Reviews.

2.1.4.4 Wavefront Correction

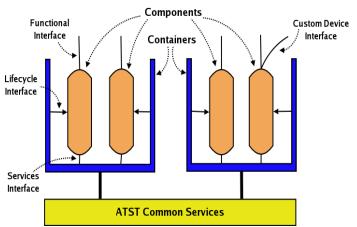
The adaptive optics design effort has made significant progress in the past year. A key risk area for the AO systems and the overall optical design was the thermal performance of the deformable mirror (DM). Early in FY 2005, Xinetics Inc. concluded a contract for the sub-scale deformable-mirror thermal design and analysis. The work was two-fold: 1) perform a thermal and thermo-mechanical analysis to understand the cooling needs and parameters; and 2) address the practicality of a 5.1 mm actuator spacing. Xinetics Inc. was eventually able to achieve our thermal requirement while retaining the 5.1 mm actuator spacing design. We are now developing a statement of work towards a contracted DM mechanical design. Other AO-related work has concentrated on identifying and defining the interfaces between the adaptive optics, active optics, guiding, and software control systems.

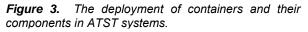
2.1.4.5 Telescope Mount Assembly

Work on the telescope mount included refinement of the design using input from the finite-element analyses of flexure and windshake, assuming a loose soil configuration. Details of the coudé lab design have evolved and significantly simplified. Analyses of tolerances with respect to the optics have also been conducted. The revisions to the coudé platform design have decreased the overall cost of the platform system.

2.1.4.6 Software

The ATST software team success-fully completed the Common Services and System preliminary Telescope Control designs in March 2005. Both systems were on fast-track design and development а schedule because of their importance to other ATST software systems. Common Services provides the communication and control structures required to operate in a widely distributed software environment, while the Telescope Control System defines the operational behavior of the telescope subsystems,





such as the mount, enclosure, and primary mirror.

Early in the conceptual design process, the ATST undertook a survey of observatory software control systems to determine the best approach to take on software design and implementation. One result of the survey was the conclusion that large, distributed software projects can reduce their overall development, integration, and maintenance costs by basing as much software as possible on a standard infrastructure. The ATST Common Services develops this infrastructure; it provides the benefits of standardized interfaces, separation of technical and application architectures, uniform implementation across all systems, and easy management in a distributed environment.

Along with the preliminary design of the Common Services the ATST has also delivered the second alpha release candidate of the operational software. This release provides a Java implementation of all technical architecture functionality, from the communications middleware through the container/component infrastructure, to the connection and event services. Future releases will provide the application architecture, expanded services, and a C++ implementation. The goal of these releases is the deployment of a fully operational beta release at the beginning of ATST construction.

In June 2004, the ATST Telescope Control System design contract was awarded to Observatory Sciences, Ltd., of Cambridge, UK. Following the Common Services review in March, Chris Mayer of Observatory Sciences and David Terrett of Rutherford-Appleton Laboratories, Oxford, UK, presented the TCS preliminary design. The design is based upon the Common Services infrastructure, giving the TCS a seamless interface with the other ATST principle systems. The TCS is also the first application designed with the Common Services in mind—the preliminary design provided a very good proof-of-concept for the Common Services.

The TCS controls the various telescope hardware systems, enclosure, the mount, primary and secondary mirrors, feed optics, wavefront correction, and acquisition camera. In addition, the provides TCS ephemeris, pointing and tracking, and time base support for the ATST. By implementing a number of virtual telescopes, the TCS can determine the position of the requested target on one or more observing focal planes. The addition of a world coordinate system and transformations between various solar coordinate systems

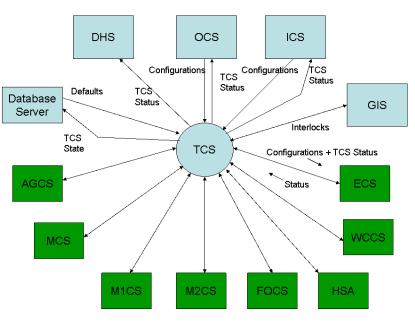


Figure 4. Telescope control interfaces.

allow users to work in many reference frames. The TCS supports heliographic, helioprojective, heliocentric, sidereal, geocentric, and topocentric coordinate systems.

Critical to the integration and operation of the ATST are the interfaces between the TCS and telescope subsystems. The TCS preliminary design delivers the first version of these software interfaces. Based upon the ATST configuration model, the interfaces identify the attributes needed for each subsystem to perform its role in delivering images to the instruments. For instance, the mount receives attributes that define its mode—whether it should datum, park, halt, move to a position, or follow a coordinate stream. The implementation and sequencing of the attributes is the responsibility of the mount. Similar interface mechanisms are also in place for the other telescope subsystems.

2.1.4.7 Systems Engineering

To allocate requirements and assess performance at a systems level, ATST systems engineering has made significant progress on the error budget for several key cases, including bottom-up performance modeling that includes statistical input from the Haleakalā site in the area of seeing, wind, and thermal properties. Tying these together with Nathan Dalrymple's thermal modeling of the M1 assembly is providing a good assessment of the range of likely performance that is guiding our design efforts.

2.1.4.8 Documentation and Interface Control

Conisio, Version 6.2, the electronic document management system, has been in use at ATST during the past year. A replication server for the Sunspot, New Mexico team members was configured and installed into the Sunspot network. Conisio enables team members to submit a file for review, and the responsible engineer(s) to review and approve the file, or return it for further work. The automatic notification of document state changes (which work via the regular email system) for configuration and interface control has also been implemented.

2.1.5 Site Survey

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

The SSWG determined ATST siting criteria, verified the validity of the site testing procedures, and prepared a final report that contains the results of the data collection and analysis effort through September 2004. That report can be found on the ATST Web site at <u>http://atst.nso.edu/site/.</u> At the time of the group's final report, site survey towers and instrumentation had been operated for approximately two years at the following three finalist sites: Big Bear Solar Observatory, California; Mees Solar Observatory, Haleakalā, Hawai'i; and Observatorio Rouque de Los Muchachos, La Palma, Canary Islands, Spain.

The SSWG presented their final report to Project Scientist Thomas Rimmele, who met with the Science Working Group (SWG) in October 2004. The SWG prepared a recommendation to the Project Director for the primary site and alternate sites on the basis of the sites' scientific quality.

The Solar Observatory Council subsequently reviewed the reports and prepared a recommendation to the AURA Board, endorsing Haleakalā, as the primary proposed site for the ATST. The AURA Board met in early January 2005 and endorsed the selection of Haleakalā, Maui, Hawai'i as the proposed location for ATST. This has allowed for significant design progress to occur in a number of areas. These include site development and environmental permitting, enclosure design, and development of the support and operations buildings.

2.1.5.1 Environmental Permitting

Environmental permitting for ATST at Haleakalā will require the preparation of a full Environmental Impact Statement (EIS) as mandated by federal and state statutes. The Maui-based firm of KC Environmental, Inc. was contracted to lead that effort, which includes sub-contracted consulting from Tetra Tech, a large national environmental engineering firm, and Charles K. Maxwell, a cultural specialist in the indigenous Maui community. The EIS contract was kicked off in May 2005 and the required Notices of Intent were subsequently published in the Federal Register. In the middle of July 2005, three formal Public Scoping Meetings were held on Maui to obtain community input on the issues that should be addressed in the EIS. At the beginning of each meeting, the ATST team presented the science case for the proposed facility. The public discussions revealed that the people of Maui are not universally in favor of the status of project development, including the EIS process, and the nature of the ATST on Haleakalā. At each meeting individuals spoke eloquently on the importance of respecting and preserving Haleakalā as a sacred place. In addition, concerns were raised about the visibility of the ATST from below due to its white

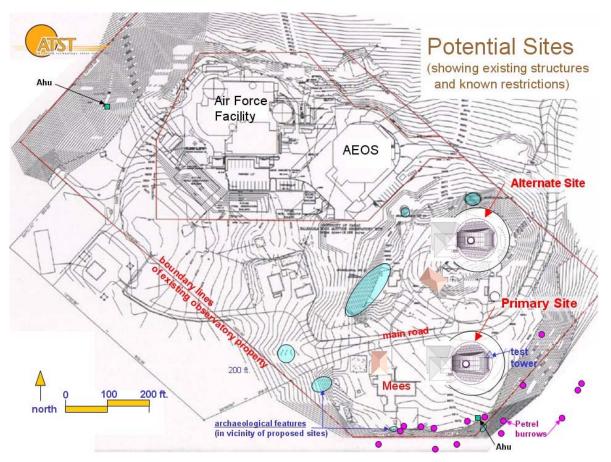


Figure 5. An overview of the primary and alternate sites, including existing structures and known restrictions.

color and required height, the potential impact of ATST on native wildlife, including the endangered Hawaiian petrel, and increased traffic on the observatory road during construction and operation of the facility. Questions were also raised about the potential economic and educational benefit ATST could offer the people of Maui. Some of these concerns were discussed at the meetings, while other deeper and more complex issues will be dealt with as part of the EIS process, which will conclude with a Record of Decision by early 2007.

To support the public meetings, a final version of the entire ATST facility (e.g., exterior building envelope) was

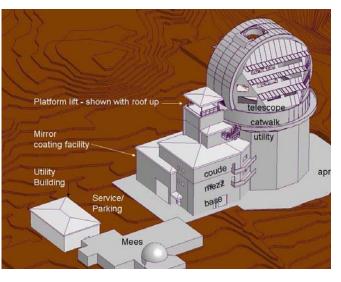


Figure 6. An aerial view of ATST at the primary site. Note the proximity to the existing Mees solar facility.

developed. Taking into account existing structures and topography, layouts of the required ATST buildings were defined for a primary and an alternate site at Haleakalā. The primary site (where the site survey test tower is currently located) is directly adjacent to the Mees Solar Observatory and would allow for potential use of this existing building for ATST support functions (see Figure 6). The alternate site is at a large flattened hill (called the Reber circle), where a radio astronomy experiment was conducted in the 1950s. This alternate site is higher than the Mees site and may offer slightly better seeing; however, this additional height and proximity to an adjacent Air Force (AEOS) telescope raise potential issues of obscuration and increased visibility of ATST from below. Both of the sites are within the boundaries of the existing 18-acre observatory, and were identified as potential locations for ATST in the recently completed Haleakalā Observatory Long-Range Development Plan.

2.1.5.2 Site Development

Investigations into power and communication availability on the summit continue. In addition, a geotechnical study was contracted and performed in early 2005. The final geotechnical report with the results of soil borings and other testing done at the primary site was received in June 2005. Volcanic sand, gravel and boulders were found near the surface, and in 5 of 6 borings, drilled to a depth of ~30 ft., relatively solid basaltic rock formations were encountered at varying depths. This finding helps to bolster our initial foundation strategy, which assumes some use of poured-concrete caissons down to competent bearing rock to help support the telescope pier and the enclosure. A combination of these caissons and a traditional wide mat foundation used on granular volcanic soils will likely form the basis of the final pier foundation design. Soil resistivity measurements and pH testing were also performed. The very high electrical resistance measurements indicate that effective electrical grounding will require special measures. A site impacts review was held in August 2005. The status of the site infrastructure design was reviewed and issues discussed with the external reviewers.

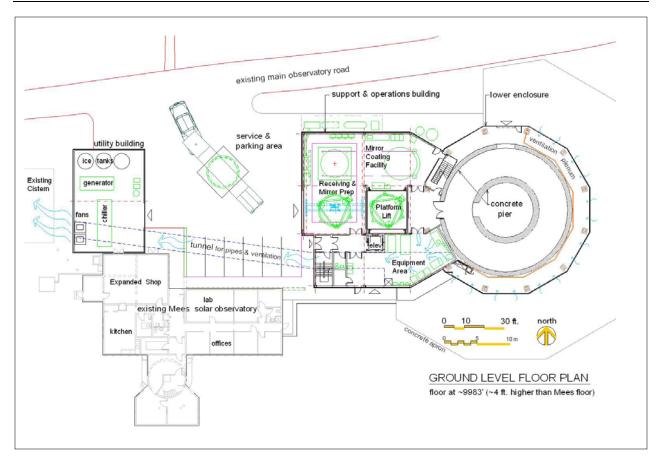


Figure 7. A ground-level floor plan of the ATST facility. The support building as three main levels: ground, mezzanine, and coudé/control-room.

2.1.6 Plans

Project plans for FY 2006 begin with convening a series of System Design Reviews (SDRs) in October 2005 and January 2006. The SDRs will cover requirements flow down, performance modeling, interface control, and overall design status. The project efforts during the remainder of 2006 will continue to focus on developing the preliminary design of the overall system. The work breakdown structure (WBS), planning, and schedule for the construction phase presented in the construction phase proposal will continue to be refined. This includes major milestones such as final or fabrication reviews, measurable fabrication stages, acceptance, shipment, integration, testing, and commissioning. Each engineer responsible for a WBS element has been detailing the plans and schedules for individual areas within the WBS, including budgets as the designs progress. Prioritization of tasks will be based on feedback from the SDRs, Science Working Group review, and contractor feedback. The project budget status will determine the extent to which we utilize major contractors throughout this phase.

Support of the EIS process, site infrastructure definition, and building designs will continue towards a record of decision planned for early 2007.

Instrumentation designs will evolve, again concentrating on impacts to the facility design. After the spectro-polarimeter instruments design review scheduled for December 2005, the subassemblies associated with polarization calibration, such as the Gregorian Optical Station, will be brought to the next level of design detail.

With science objectives in mind, key observing scenarios continue to be worked out to better understand and develop operations planning. Decisions on the level of contractor involvement in the remaining design effort, based upon evaluations in process, will affect the details, timing and format of remaining reviews. Project efforts continue toward early procurement of the primary mirror blank.

2.2 Synoptic Optical Long-term Investigations of the Sun (SOLIS)

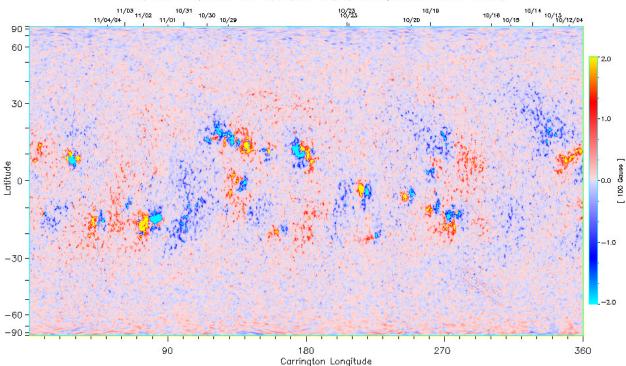
SOLIS is a project to obtain optical measurements of processes on the Sun, the study of which requires well-calibrated, sustained observations over a long time period. The project was conceived in 1995, proposed to the NSF in January 1996, and received partial funding in January 1998. The design and construction phases required five years. The 25-year operational phase of the major instrument started late in FY 2003.

As funded, SOLIS comprises three instruments initially mounted on the top of the refurbished Kitt Peak Vacuum Telescope tower. The mounting is transportable so that SOLIS can be moved to a different site in the future. The three full-disk instruments on a common mount are: (1) A Vector Spectromagnetograph (VSM) to measure the strength and direction of the photospheric magnetic field, the line-of-sight component of the chromospheric magnetic field, and the spectral line characteristics of the helium chromosphere; (2) a Full-Disk Patrol (FDP) that provides digital, one-arcsec pixel images of the full disk, showing the intensity and line-of-sight velocity in a number of spectrum lines at high cadence; and (3) an Integrated Sunlight Spectrometer (ISS) that furnishes Sun-as-a-star spectra at both high and medium spectral resolutions with emphasis on high photometric precision and stability.

The productivity of SOLIS is enhanced when working in concert with other observing projects, both in space and on the ground—in particular, currently operating space missions, including the Solar and Heliospheric Observatory (SOHO), Transition Region and Coronal Explorer (TRACE), and Ramaty High Energy Solar Spectroscopic Imager (RHESSI), as well as future missions, such as the Japanese SOLAR-B (08/2006) and NASA's Solar TErrestrial RElations Observatory (STEREO) (04/2006) and Solar Dynamics Observatory (SDO) (08/2008). SOLIS also provides contextual data for high-resolution DST and McMP observations, making the observations more valuable for understanding magnetic field evolution and solar activity.

This report covers the period October 2004 through September 2005 of the startup phases of the 25-year SOLIS project. During this period, emphasis continued on completion of major elements of the SOLIS system, and initial observing with the VSM. SOLIS data are now being used for research and operational purposes.

The VSM regularly produces high quality full-disk magnetograms of the Sun that are far superior to those from its predecessor, the Vacuum Telescope and spectro-magnetograph. A major component of SOLIS is data processing, distribution and archiving. A Storage Area Network located on Kitt Peak now collects the raw observations in real time. A data processing pipeline that runs on a Linux cluster automatically reduces the observations. The reduced observations are transferred to Tucson via a 45-MB-per second data link, after which they promptly appear on the SOLIS Web site along with a variety of derived data products such as synoptic maps. An example of a magnetic flux synoptic map is shown in Figure 8. This example was made during a period of relatively high solar activity. The level of solar activity has since dropped and is approaching a minimum.



NSO/VSM Magnetic Flux Synoptic Map (Carrington Rotation: 2022)

Figure 8. An example of a product of SOLIS daily magnetic measurements. This false color image indicates the density of the radial component of the Sun's magnetic flux. Daily observations were combined in this image to make a map showing the flux distribution over the entire solar disk. These data are used to predict space weather.

The VSM suffered from a slow degradation of the polarization modulator that allows the full vector magnetic field to be measured. This complicated our calibration efforts and slowed release of the regular vector magnetic field observations obtained with the instrument. A replacement modulator is being constructed and will be installed around the end of 2005. At the same time, a new modulator will be installed for measurement of the line-of-sight component of the magnetic field in the solar chromosphere. This new modulator will significantly increase the strength of the chromospheric signal. A considerable effort has been expended in developing a method for removing the ambiguity in vector magnetic field observations made with SOLIS. This problem refers to the fact that measurements of the component of the magnetic field in the plane of the sky have two possible directions that cannot be distinguished solely on the basis of the observations. A method for resolving this ambiguity that looks promising is to use the solenoidal property of magnetic fields along with a determination of the sign of the gradient of the magnetic field along the line of sight. The latter can be determined from our simultaneous observations made at two slightly different heights in the solar atmosphere. When this problem is solved, maps such as Figure 8 can be constructed on a daily basis and will allow more rapid and accurate prediction of solar wind speeds.

Observations of the strength of the helium 1083 nm spectrum line have been made with the VSM since it started operation. The detectors used are subject to strong interference fringing at that wavelength and it was thought that elaborate processing would be needed to get a useful signal. It turned out that a simple processing method does an adequate job as indicated in Figure 9.

Observations like that in Figure 9 over a period of days can be combined to construct synoptic maps of coronal hole locations. These maps show where fast solar wind originates and are useful in both operational and research activities. A recent example is shown in Figure 10.

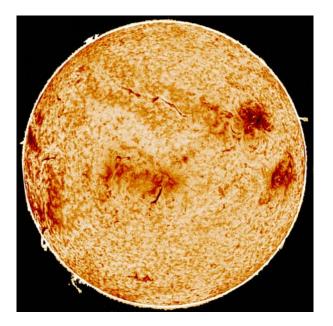


Figure 9. This false color image of the solar chromosphere was made with the SOLIS VSM. It shows the strength of the 1083 nm line of He I. Large dark blobs are hot solar active regions, elongated dark structures are clouds of cool gas suspended above the surface and seen as bright features above the solar limb. The mottled appearance of most of the disk indicates areas with varying density of chromospheric material. The large light area with reduced mottling, slightly above and to the left of disk center, is a socalled coronal hole from which fast solar wind blows into interplanetary space. The fast solar wind from coronal holes causes geomagnetic storms when it impinges on Earth's magnetosphere.

NSO/VSM (Preliminary) Solar Wind Source Map (Carrington Rotation: 2035_168.0)

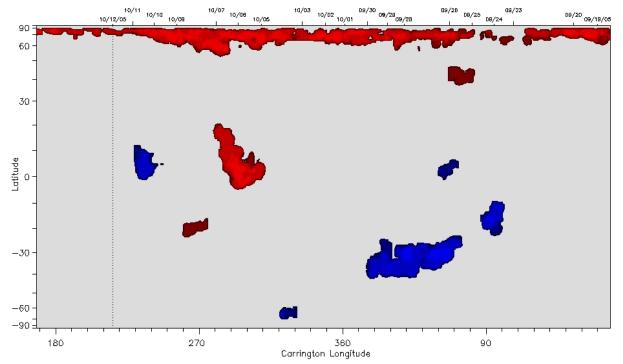
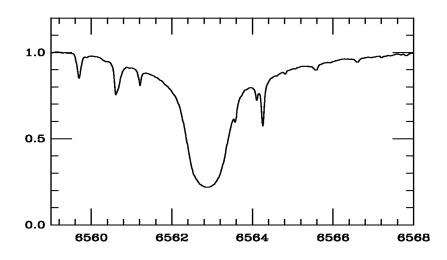
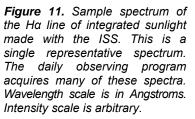


Figure 10. A synoptic map showing the locations of coronal holes from which fast solar wind originates. The colors distinguish which magnetic polarity is associated with each hole and the saturation of the color indicates the permanence of the holes. A blue south polar hole is not shown here.

The ISS is a double-pass grating spectrograph equipped with a CCD camera in its final focal plane and fed by a number of optical fibers. Its purpose is to measure changes of selected lines in high-quality spectra of the Sun with no spatial resolution, i.e., like a star. The instrument is installed one floor beneath the SOLIS mount in a temperature and humidity controlled room on an air-supported table to reduce vibrations. Two of the fibers are fed by small lenses that form images of the Sun on the end of the fibers. Uranium-argon (UA) and thorium-argon (ThAr) emission lines are used for wavelength calibrations. Sunlight fed to one of the fibers passes through an iodine vapor cell that serves as a superimposed stable wavelength reference for ultra-high precision Doppler shift measurements. Sunlight is thoroughly scrambled by the time it passes through the fibers into the spectrometer. A CCD television camera and an optical system that simultaneously forms images of the Sun at five different wavelengths measure terrestrial atmospheric extinction across the solar disk. A sample spectrum of the H-alpha line of integrated sunlight is shown in Figure 11.





The FDP is the least unique of the SOLIS instruments and has not yet been completed since priority was given to the VSM and ISS. The FDP is currently located in a Tucson lab where it can be fed with sunlight from a rooftop heliostat. The FDP is designed to make full-disk images of the Sun in selected narrow wavelengths. It is equipped with two 2000×2000 pixel CCD cameras and presently has two filters installed; one for H-alpha and one for the 1083 nm He I line. A tunable filter covering the range from 380 – 670 nm is under construction as time and personnel availability permit and will replace the H-alpha filter. All of the optical components for the tunable filter have been acquired. The FDP is being used as a test bed for the guider, which is identical for the VSM and FDP.

Daily SOLIS operations have been limited by personnel availability to about five hours. The short observing day is mainly a consequence of the unexpected loss of observing support from former partners in operating the synoptic observing program. To partly fill this gap, and extend the amount of observing, a proposal was submitted to NASA's Living With a Star (LWS) program and was accepted for funding. This funding is now being used to support an additional observer and two research scientists to help realize the scientific potential of SOLIS data.

Transition from manual, engineering-style observing to automated or remote observing is expected to take several years with the present level of programming assistance that is assigned to SOLIS. A program of

acquiring long-lead-time spare parts for SOLIS was started. The first result of this effort is development of a replacement Data Acquisition System for the VSM. We presently use a custom unit and spares are no longer available. A far cheaper unit can now be built using commodity parts with higher performance levels than the original unit. The possibility of replacing the interim cameras used in the VSM with newly available units much closer to the original SOLIS design is under active investigation.

Acquired raw data are reduced by pipelines for each instrument and then transported to Tucson, where it is archived and made available to the user community through the Virtual Solar Observatory (VSO), the NSO Digital Library, or via a SOLIS Web site. Several organizations are already making use of the data. Developing and coding the reduction algorithms is a long and difficult process to ensure that the intrinsic high quality of the data is preserved and fully utilized. Four PhD scientists are doing this at part-time levels that range from a few percent to about 75 percent.

In the National Research Council's most recent ten-year plan, "Astronomy and Astrophysics in the New Millennium," an expansion of SOLIS from one installation to a three-site network is the highest priority small solar initiative, and third priority following the Advanced Technology Solar Telescope (ATST) and the Frequency Agile Solar Radiotelescope (FASR) as ground-based solar projects. The cost of this extension was estimated at \$4.8M and an additional \$200K per year for operations. Preliminary plans suggest duplicating SOLIS except for the ISS and FDP, for which arguments for high continuity of observation and uniqueness are not as strong as for the VSM. This would allow a collaborating foreign partner and site host to use the declination axis normally used for the FDP and ISS to mount an instrument of their own for their own research purposes. Some informal contacts with potential international partners have been made with interest being expressed. No concrete plans have been developed as efforts have been focused on making the present SOLIS instruments fully operational.

An interesting possibility that is being studied would join SOLIS and the Improved Solar Observing Optical Network (ISOON) in a three-site network consisting of the SOLIS VSM providing magnetograms and ISOON providing narrowband imagery and a common data base system. Such a combination may be of interest to the US Air Force for its operational needs. The research emphasis of SOLIS would have to be preserved in such an arrangement. Another potential funding opportunity is afforded by a developing Major Research Equipment (MRE) initiative at the National Science Foundation called Distributed Arrays of Small Instruments.

2.3 High-Order Adaptive Optics

Since August 2000, the NSO, in primary partnership with the New Jersey Institute of Technology (NJIT), has been developing high-order solar adaptive optics for use at the 65-cm telescope at Big Bear Solar Observatory (BBSO) and the 76-cm Dunn Solar Telescope (DST) at Sacramento Peak. The National Science Foundation has sponsored this project within the Major Research Instrumentation program with substantial matching funds from the participating partner organizations, which include the NSO, the NJIT, the Kiepenheuer Institute in Germany, and the Air Force Research Laboratory.

The NSO AO program, led by Thomas Rimmele, continues to make significant progress, with the loworder AO system at the DST being upgraded to high-order (76 degrees of freedom) in 2004 and the conduct in 2005 of successful multi-conjugate adaptive optics (MCAO) observing runs at the DST. Additional MCAO observing runs as well as detailed MCAO performance evaluations are currently being conducted. There are two high-order AO systems in the DST, one feeding the new Diffraction-Limited Spectro-Polarimeter (DLSP) and the other feeding the Advanced Stokes Polarimeter (ASP) and the narrowband filter of the Italian Interferometric BIdirectional Spectrometer (IBIS). Both ports have room to set up additional filters and cameras. The port with the DLSP is dedicated to the DLSP and the setup frozen to minimize set-up time between users.

Section 4.4 shows an ultrasharp image of Sunspot AR 10810 made possible by the recently completed AO76 advanced adaptive optics image correction system and new high-resolution CCD camera at the DST.

2.4 Global Oscillation Network Group (GONG)

The Global Oscillation Network Group is an international, community-based program conducting a detailed study of the internal structure and dynamics of the Sun by measuring acoustic waves that penetrate throughout the solar interior. In order to overcome the limitations of observations imposed by the day-night cycle at a single observatory, GONG operates a six-station network of extremely sensitive and stable solar velocity mappers located around the Earth, obtaining nearly continuous observations of the "five-minute" pressure oscillations.

The instruments obtain 800×800 velocity, intensity, and magnetic flux images once a minute with a duty cycle near 90%. Data products, including individual images, time series, *p*-mode frequencies, and "science products" such as flow maps are available online at <u>http://gong.nso.edu</u>.

Observations and analysis of the low-degree, global *p*-modes continue to track the evolution of the interior through the solar cycle and we now have excellent measures of the propagation of the torsional oscillations (regions of faster and slower rotation) propagating toward the equator, and—having seen the long-standing neutrino deficit resolved in favor of the Sun and supporting new physics of the neutrino—are watching the debate around the substantial changes in the internal structure implied by a proposed, new lower value of the heavy element abundance (Z).

Data processing operations in Tucson continue to become more automated and efficient with the implementation of computer servers, shared resources, and process-controlled pipelines. The GONG++ data processing pipeline system continues to make excellent progress towards achieving routine scientific operations for processing the higher resolution data. This new focus is on high-degree ($\ell \approx 1000$) global pmode processing to probe closer to the solar surface and local helioseismology methods-tracking and remapping ring diagrams, time distance, and holography-to probe the inhomogeneous and intermittent structure below the surface. The ring-diagram analysis, which yields "subsurface solar weather" flows, remains the principal technique being exploited, and the first 44 consecutive Carrington rotations (1188 days) have been generated. Travel time measurements ("time-distance helioseismology") of the meridional flows down to the base of the convection zone, going back to the beginning of GONG, have been derived, and a routine time-distance pipeline is eminent in FY 2006. An automatic pipeline that produces daily maps of the back, or "farside," of the Sun with near-real-time data has been completed. These data should help forecast active regions up to two weeks before they rotate into view, thus providing useful information to a broad range of users from solar astronomers planning upcoming observing campaigns to space weather forecasting. Calibration of the signal is the next challenge. See Section 4.3 science highlight, "The GONG Farside Project: Seismic Imaging of active region AR-10808."

In addition to helioseismic data, GONG provides photospheric line-of-sight magnetograms and intensity images in the 6768A Ni line. The high-time-cadence magnetograms are useful in many solar physics

studies, but are at present used mostly in helioseismology. In addition to complementing the SOLIS data and supporting the STEREO mission by providing a continuous temporal context, a Magnetogram Users Group was formed to evaluate the usefulness of the magnetograms and make recommendations to improve the quality and make the new GONG++ magnetogram data products available to a broad scientific community. At present, the zero point error across sites is the largest error in the GONG magnetograms and limits their scientific use. A new polarization modulator and accompanying electronics, which will significantly reduce the zero point uncertainty (from about 10 G to 0.3 G), will be installed around the network by April 2006, making way for the routine production of quality magnetogram data products.

The site and instrument operations team continues to face the challenge of maintaining and improving network reliability and maintainability, but is now also looking to the opportunities of increased communications bandwidth, which should result in near-real-time data verification and diagnostics, better performance, and eventually near-real-time data transfer and science. In order to mitigate the risk of losing a site catastrophically, which would jeopardize the future of the program as result in the irretrievable loss of data and a very large budgetary demand, the engineering team is building a complete "hot spare" station. Building a spare instrument also preserves the critical function of the engineering site, which is fundamental to maintaining the ability to address and anticipate field problems with proven solutions, as well as providing an essential test bed for development and upgrade of replacement technologies or possible new capabilities.

2.5 Virtual Solar Observatory (VSO) and Digital Library

In FY 2005, NSO continued to lead the development of the Virtual Solar Observatory (see <u>http://vso.nso.edu/</u>), a unified distributed solar data archive and analysis system with access through the Internet. Version 1.2 of the system was released for public use on May 20, 2005. Since December 2004, approximately 7,500 searches have been performed using the VSO, which provides access to data from 112 different observatory/instrument sources, both space- and ground-based. The data can be searched on the basis of observatory or instrument, physical observable, time, event, and spectral range. The VSO provides two types of interfaces—a Web-based interface for browsing, and an Application Programming Interface (API) so that users can access the VSO directly from their own personal software. In FY 2005, further development of the VSO was completed, providing an adopter's kit to install additional archives and a shopping-cart style search storage mechanism. In FY 2006, the VSO development will include an IDL interface, the ability to select data on the basis of spatial area, and an improved user interface. The VSO is being constructed by NSO, NASA Goddard Space Flight Center, Stanford University, Montana State University, and Southwest Research, Inc.

The need for a VSO is clearly demonstrated by the experience of NSO in providing synoptic data sets over the Internet to the research community. In FY 2005, the NSO Digital Library distributed nearly 600,000 files on average each quarter to approximately 600 users, an increase of 50% compared to FY 2004. These figures exclude any NSO or NOAO staff members. Currently, the Digital Library holds the entire set of daily solar images from the Kitt Peak Vacuum Telescope, Fourier Transform Spectrometer data, a portion of the Sacramento Peak spectroheliograms, GONG data, and SOLIS magnetograms. With the advent of the VSO, solar researchers as well as educators and the general public will be able to easily find solar data for their research or educational needs.

3 SCIENTIFIC AND KEY MANAGEMENT PERSONNEL

The NSO staff is located in Sunspot, New Mexico and Tucson, Arizona. The observatory director is Dr. Stephen L. Keil, who is based in Sunspot but spends time at both operational sites. Dr. Mark S. Giampapa is deputy director and responsible for the Tucson operations. Mr. Rex Hunter is site manager at Sacramento Peak at Sunspot. Mr. Steve Hegwer is the project and telescope manager at Sunspot, and Ms. Valorie Burkholder is the project and telescope manager in Tucson. Mr. Jeremy Wagner is the ATST project manager. Ms. Patricia Eliason is the GONG facility manager, and Mr. Dave Dooling is the ATST/NSO educational outreach officer. NSO and affiliated scientific staff are listed below, along with their primary area of expertise and key observatory responsibilities.

Sunspot-Based Scientific Staff

NSO Staff

- K. S. Balasubramaniam Solar activity; magnetism; polarimetry; ATST narrowband imager; International Heliophysical Year liaison and editor of the *IHY Newsletter*.
- Stephen L. Keil NSO Director; ATST PI; solar variability; convection.
- Alexei A. Pevtsov Solar activity; coronal mass ejections, Site Director, NSO REU/RET Program; ATST broadband imager.
- Thomas R. Rimmele Solar fine structure and fields; adaptive optics; instrumentation; ATST Project Scientist; Dunn Solar Telescope Program Scientist; ATST/AO program lead.
- Han Uitenbroek Atmospheric structure and dynamics; radiative transfer modeling of the solar atmosphere; Ch., NSO/SP Telescope Allocation Committee; ATST thermal IR.

Grant-Supported Staff

- K. Sankarasubramanian Solar fine structure; magnetism; Stokes polarimetry; ATST polarimetry.
- Alexandra Tritschler 2D spectroscopy and spectropolarimetry of sunspots and pores in the solar photosphere; instrumentation.

Air Force Research Laboratory Staff at Sunspot

- Richard C. Altrock Coronal structure and dynamics.
- Nathan Dalrymple Polarimetry; ATST thermal analysis.
- Joel Mozer Coronal structure; remote sensing; space weather.
- Richard R. Radick Solar/stellar activity; adaptive optics.

Thesis Students

- Hyun Kyoung An ATST instrumentation.
- Brain Lundburg Solar activity; magnetism; polarimetry.
- Jose Marino Adaptive optics; solar imaging.

Tucson-Based Scientific Staff

NSO Staff

- Olga Burtseva Helioseismology.
- Mark S. Giampapa NSO Deputy Director; stellar dynamos; stellar cycles; magnetic activity; Ch., Tucson Project Review Committee; Ch., Scientific Personnel Committee; SOLIS PI.
- John W. Harvey Solar magnetic and velocity fields; helioseismology; instrumentation; SOLIS Project Scientist; Ch., NSO/KP Telescope Allocation Committee.
- Carl J. Henney Solar MHD; polarimetry; space weather, SOLIS Facility Scientist.

- Frank Hill Solar oscillations; data management; GONG Program Scientist.
- Rachel Howe Helioseismology; the solar activity cycle.
- Shukur Kholikov Helioseismology; data support.
- John W. Leibacher Helioseismology.
- Matthew J. Penn Solar atmosphere; solar oscillations; polarimetry; near-IR instrumentation; Co-Site Director, NSO REU/RET Program; ATST near-IR.
- Clifford G. Toner Global and local helioseismology. Image restoration; data analysis techniques.

Grant-Supported Scientific Staff

- Michael Dulick Molecular spectroscopy; high-resolution Fourier transform spectrometry.
- John A. Eddy Solar-Terrestrial physics; Earth system science; history of the Sun and Climate
- Irene E. González-Hernández Local helioseismology; ring diagrams and holography.
- Harrison P. Jones Solar magnetism and activity.
- Rudolph W. Komm Helioseismology; dynamics of the convection zone.
- Nour-Eddine Raouafi Solar magnetic fields.
- William H. Sherry Evolution of stellar activity; protoplanetary disks.
- Sushanta C. Tripathy Helioseismology; solar activity.
- Roberta M. Toussaint Helioseismology; image calibration and processing; data analysis techniques.

4 SCIENTIFIC RESEARCH AND DEVELOPMENT HIGHLIGHTS

4.1 Quiet Sun Magnetic Fields at High Angular Resolution

The weak, small-scale fields of the quiet Sun "internetwork" regions have been the subject of considerable scientific scrutiny recently. New observations have attained both higher sensitivity and higher angular resolution, revealing a wealth of small-scale structure, and demonstrating that the net "unsigned" flux of the Sun rivals, or even exceeds, that of the 11-year-period solar active region fields, and even that from the intense flux concentrations at the boundaries of the quiet solar supergranular network pattern. Theorists have also examined the internetwork fields and speculate that a local, small-scale dynamo may be acting to produce those fields. The reality of this dynamo process, and the influence that the small-scale mixed polarity internetwork fields have upon heating and dynamics of the solar atmosphere, are issues that are of considerable prominence in solar physics today.

A recent observational study suggested that upon a modest enhancement of angular resolution, the amount of unsigned internetwork flux increases dramatically. This implies that we are far from resolving the tangled magnetic field structure of the internetwork, and that the total magnetic energy of these fields may be much larger than previously believed.

The new Diffraction-Limited Spectro-Polarimeter (DLSP) at the NSO Dunn Solar Telescope (DST) is ideally suited to explore this topic. In combination with adaptive optics systems now in place at the DST, much higher angular resolution of the internetwork fields may be achieved, while maintaining very high polarimetric sensitivity. High spatial resolution is necessary to better resolve the tangled small-scale field, and high polarimetric sensitivity is necessary to detect the intrinsically weak and small-scale magnetic elements. The DLSP is based on the same spectro-polarimetric technique as its predecessor, the Advanced Stokes Polarimeter (ASP), which provides spectrally resolved, simultaneous line profiles in all four Stokes polarization parameters. Among extant techniques, spectro-polarimetry yields the most complete and unambiguous inferences of magnetic fields in the solar atmosphere.

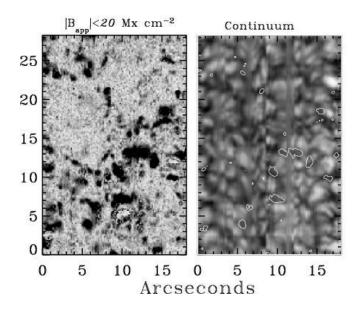


Figure 12. Observations of a small patch of quiet Sun from the Diffraction-Limited Spectro-Polarimeter on 16 September 2003 reveal the very weak fields of the "internetwork" regions. Left: |B_{app}|, the unsigned apparent flux density, scaled so that maximum strength (dark) corresponds to 20 Mx cm⁻². Right: Continuum intensity from the spectral map used to generate the image on the left, with contours of 32 Mx cm⁻ superimposed. Other studies, based upon newer but unproven observational techniques. would have all the dark intergranular lanes occupied by strong field mixed polarity elements (i.e., such contours would cover most of the dark lanes in this map). Vertical stripes are caused by variable seeing. The now completed DLSP, in conjunction with the new high-order adaptive optics system at the Dunn Solar Telescope, yields maps of uniform (and better) image quality.

In September 2003 a prototype version of the DLSP provided measurements of very quiet solar regions during periods of variable seeing. These data do not approach the quality expected from the now completed DLSP, in that components pieces of the ASP were used in the system, and the old low-order adaptive optics system was still in place. Nonetheless, at better than 0.6 arcsec resolution these measurements represent the highest spatial resolution precision spectro-polarimetry of the quiet Sun yet obtained.

The results are illustrated in the figure, where the inferred apparent magnetic flux density $|(B_{app})|$ is shown at high sensitivity on the left panel for a small patch of quiet Sun. The right panel shows the corresponding continuum intensity ("granulation") with contours of $|B_{app}| < 32$ Mx cm⁻². These results demonstrate that it is far from the case that most intergranular lanes are occupied by strong flux elements. In fact, the net unsigned flux of these DLSP measurements is not much different from older ASP measurements at half the spatial resolution. Note also extensive regions devoid of significant flux at this polarimetric sensitivity (which is some factor of 10 better than that of those recent observations suggesting otherwise).

These DLSP observations suggest that the complexity and the net unsigned flux of quiet internetwork regions in fact DOES NOT increase rapidly at smaller scales. These early results must be verified by the much more capable final version of the DLSP. Such observations are now scheduled, and will examine the properties of the quiet Sun internetwork fields in various regions of quiet Sun large-scale structure.

For detailed information, see: Lites, B. W. & Socas-Navarro, H. 2004, ApJ, 613, 600.

4.2 Magnetic Field Changes during Solar Flares

Solar flares are the most energetic events in the Solar System, resulting in the acceleration of elementary particles to relativistic speeds and the emission of radiation across the electromagnetic spectrum. Finding the trigger for these events has been a goal of astrophysics since frequent observations of solar flares began in the 1920s. Because the solar magnetic field is the most reasonable source of energy to power solar flares, observations to detect changes in the magnetic field have been attempted for more than 50 years. Since 1999, as a result of improvements in ground-based and space-based instrumentation, changes in the local magnetic field during flares have been reported for 14 X-class solar flares in 20 publications. Most publications have presented results for a single event. The sources of data and the methods of analysis across these publications are quite inhomogeneous, and given the small number of events, some doubt about the phenomenon has lingered.

Magnetograms from the global network of GONG telescopes have afforded NSO scientists Jeff Sudol and Jack Harvey with a unique opportunity to assess the characteristics of magnetic field changes during solar flares for a large number of events. The GONG magnetograms, which show the line-of-sight component of the photospheric magnetic field across the entire solar disk, are available at a one-minute cadence. The magnetograms have a spatial resolution of 5 arcseconds and an instrumental noise of about 3 G. In order to characterize the magnetic field changes during solar flares, 15 X-class flares were selected for which continuous magnetograms from a single GONG site were available for at least one hour before and after the peak of the flare.

Sudol's and Harvey's major findings are as follows.

- During all 15 flares in their sample, an abrupt, significant, and permanent field change in the longitudinal magnetic field occurred in at least one location in the active region. Most of the field changes occurred in the penumbrae of sunspots.
- In three cases, they have continuous sets of X-ray images from the TRACE satellite that overlap with the GONG data. In all three cases, they find excellent spatial and temporal correlation between changes in the magnetic field and changes in the bright features in the TRACE images.
- In six cases, the change in the magnetic field appears to propagate across the active region at rates between 5 and 30 km s⁻¹, comparable to the rates at which H α ribbon flares move.
- In one case, they have a continuous set of $H\alpha$ images that overlap with the GONG data. In this one case, the $H\alpha$ ribbon flare moves in the same direction and at the same rate as the change in the magnetic field.

Sudol and Harvey have established without question that changes in the magnetic field are a common phenomenon during (at least the X-class) solar flares. Because the full field vector is not observed, the interpretation of these results is ambiguous. Among several possible scenarios, they favor one in which the observed change in the longitudinal field is a result of the vector field becoming more vertical as an immediate consequence of the flare. If their favorite scenario is correct, work is associated with the tilting of the field and this work must be included in the energy budget of any theory. At present, flare theories assume that the photospheric magnetic field does not change during the flare. In light of their results, this assumption must be revisited.

Because the field changes always occur after the flare start, they conclude that the observed field changes do not trigger flares but represent another post-flare phenomenon. Still, the observed field changes may help sort out the basic physics of the flare phenomenon. The details of this work are scheduled to appear in the 10 December 2005 issue of the *Astrophysical Journal*.

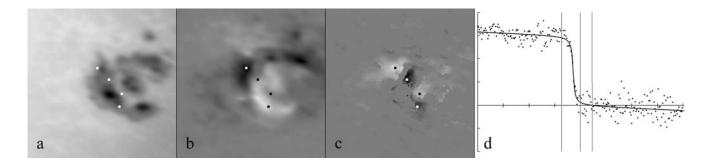


Figure 13. (a) A remapped GONG "white light" image of the flaring active region on 02 Nov 2003. The image is 128 pixels square. The image scale is 0.125° per pixel in heliographic coordinates. (b) A remapped GONG magnetogram of the same active region. Black indicates negative field, white, positive field. (c) A map of the fit parameter for the change in the magnetic field. Black indicates a decrease in the field, white, an increase. The black and white boxes in each image denote the positions of the representative points used in our analysis. The box color is not important. (d) A plot of the longitudinal magnetic field as a function of time for one of the representative points. The black line represents the fit to the data. The three vertical lines denote the start, peak, and end of the flare according to GOES X-ray flux measurements. The vertical axis spans 300 G, and tick marks appear at an interval of 50 G. The horizontal axis spans 240 minutes, and tick marks appear at an interval of 30 minutes.

Farside map

4.3 The GONG Farside Project: Seismic Imaging of Active Region AR-10808

GONG is now continuously calculating farside maps of the Sun using the helioseismic holography technique developed by Lindsey and Braun (1997, ApJ). The technique is based on the fact that sunspots behave as both absorbers and scatterers of helioseismic waves (Braun, Duvall & LaBonte, 1988, ApJ), causing a seismic deficit that can be detected at the antipode of the sunspot. Large active regions leave a signature in the low-degree global *p*-modes that travel completely through the Sun without loss of coherence. These modes can be detected using Dopplergrams of the near side of the Sun obtained by the GONG instrument. The waves are then analyzed to extract information about their interference with magnetic regions along their path.

The method has proven its ability to locate large sunspots on the farside solar surface and track their migration before they emerge to face the Earth. Each farside map, which is updated and displayed every twelve hours, uses a 24-hour-period of near-real-time images sent to Tucson from GONG's six worldwide network stations. The current farside maps, along with archived data, a movie, and links of interest, can be found at <u>http://gong.nso.edu/data/farside</u>. Cooperative synoptic seismic imaging of the farside of the Sun using GONG and the Michelson Doppler Imager (MDI) instrument onboard SOHO will facilitate space weather forecasting. The goal for the near future is to generate full-hemisphere farside images, as well as imaging the solar poles.

30 Aug 2005

Figure 14 shows four farside maps of the Sun, from August 30 to 09 September 2005, as they track the evolution of active region AR-10808. The farside maps extend 45 degrees from the center of the non-visible disk at each particular time. They are projected into a longitude-sin (latitude) grid with the equator and meridians 60-degrees apart, denoted by the grid lines. In the lower section of the figure, a farside image shows a quiet Sun compared to the adjacent image of the simultaneous front side, obtained from GONG magnetograms, which shows AR-10808 near the limb of the Sun on 09 September 2005. The huge X-17 flare, produced by this active region as it emerged on the East limb, is shown in Figure 15. It is the fifth most intense solar flare on record and was captured by the Solar X-ray Imager on board the GOES satellite on September 7, dramatically coinciding with the migration of the sunspot as shown in the GONG farside maps from the previous days.

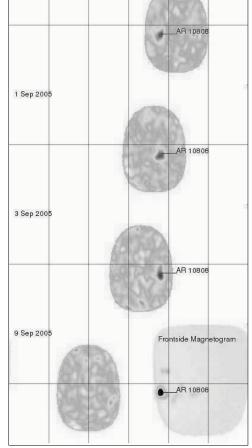


Figure 14. GONG farside maps of the Sun, from August 30 to September 30, 2005, as they track the evolution of active region AR-10808. In the lower right corner of the figure is an image of the simultaneous front side of the Sun, obtained from GONG magnetograms, which shows the active region (AR-10808) near limb of the Sun on 09 September 2005.

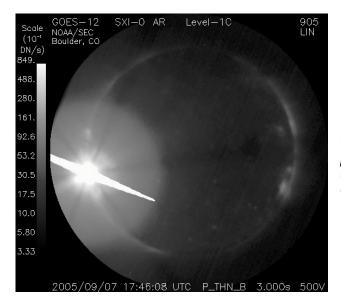
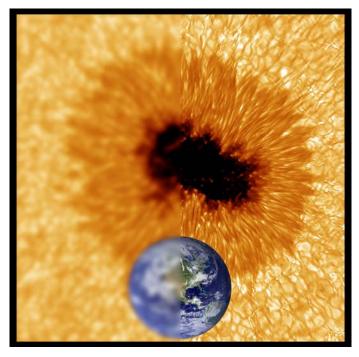


Figure 15. The Solar X-ray Imager onboard the GOES satellite captured the huge X-17 flare produced by AR-10808 on 07 September 2005 (image is from the Virtual Solar Observatory, cart ID:VSO-NSO-051017-068).

4.4 Ultrasharp Images Produced by the Dunn Solar Telescope High-Order Adaptive Optics (AO76) System

A scaled image of Earth superimposed on sunspot AR 10810 depicts the enhanced resolution possible with the Dunn Solar Telescope's high-order adaptive optics (AO76) system. G-band (430.5 nm) bright points, which indicate the presence of small-scale magnetic flux tubes, are seen near the sunspot and between several granules. The dark cores of penumbral fibrils and bright penumbral grains are seen as well in the sunspot penumbra (fluted structures radiating outward from the spot). These features hold the key to understanding the magnetic structure of sunspots and can only be seen in ultra high-resolution images such as this one. Magnetism in solar activity is the "dark energy problem" being tackled in solar physics today. This image was built from 80 images, each 1/100th of a second long (10 ms), taken over a



period of 3 seconds by a new high-resolution Dalsa 4M30 CCD camera in its first observing run coupled to the AO76 system at the Dunn on 23 September 2005. Speckle imaging reconstruction then compiles the 80 images and greatly reduces residual seeing aberrations. The left half of the image is artificially blurred to simulate uncorrected seeing; the right half of Earth is blurred to resolution comparable with the Dunn's 0."14 resolution with AO. The image was taken and processed by Friedrich Wöger, a graduate student from the Kiepenheuer-Institut für Sonnenphysik in Freiburg, Germany, with the assistance of Chris Berst of NSO. Wöger started working with Thomas Rimmele as a summer 2005 student.

4.5 New Interest in an Old Line

The He I 1083 nm spectral line is of great interest to both solar and stellar physicists since it is formed at a crucial layer of a stellar atmosphere between the top of the chromosphere and base of the transition region, where the temperature begins an abrupt rise from surface (10,000 K) to coronal (1,000,000 K) values. Spectroheliographic images of He I 1083 nm equivalent width have been obtained at the NSO Kitt Peak Vacuum Telescope (KPVT) for 30 years, and show a wealth of solar phenomena including, in particular, coronal holes, a source of high-speed solar wind. In 1992, the capability for obtaining true imaging spectroscopy in this important line was initiated with the NASA/NSO spectromagnetograph (SPM) and now continues in more advanced form with the new SOLIS vector spectromagnetograph (VSM).

Spectroscopically, the 1083 nm line is very difficult to reduce and analyze since it is weak, highly variable in both space and time, and blended with nearby solar and telluric lines. Over several years, Harrison Jones (NASA/NSO) and Olena Malanushenko (NSO) have obtained imaging spectroscopy of coronal holes and other interesting features with the SPM and have developed new techniques for dealing with the data. Results of this effort include development of methods for removing spectral lines from flat-field images of the average solar spectrum (Jones, 2003, *Solar Physics*, **218**, 1) and for accurate separation of line and continuum using a well-calibrated standard (Malanushenko and Jones, 2004, *Solar Physics*, **222**, 43).

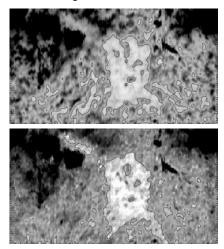


Figure 17. He I 1083 nm equivalent width, 02 February 2004. First reduced data from the SOLIS VSM.

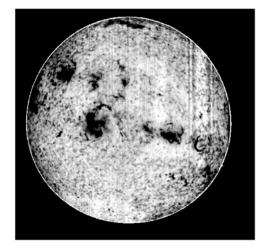


Figure 18. Top: He I 1083 nm central intensity with 1% contrast contour for SPM observations on 17 April 2000. Bottom: Sum of statistically normalized intensity and half-width images with 1-sigma contour.

Malanushenko and Jones (2004, *Solar Physics*, in press) have recently discovered that line width and central intensity are negatively correlated in the quiet Sun but have a different relation in coronal holes. As shown in Figure 17, adding statistically normalized images of intensity and width (bottom panel) suppresses the appearance of chromospheric network and enhances the contrast between coronal holes and quiet Sun, areas which are often difficult to separate in images of central intensity alone (top panel). This characteristic promises to allow development of a new objective and automated method for coronal hole recognition.

In another important development, Malanushenko has produced equivalent width images of the 1083 nm line from VSM observations in spite of strong fringing in the detectors. The first full-disk 1083 nm image from the VSM, which replaces the KPVT and SPM, is shown in Figure 18.

4.6 Spatial Distribution of Sodium on Mercury

Andrew Potter (NSO), Rosemary Killen, and Menelaos Sarantos (University of Maryland) are mapping the sodium emission from planet Mercury using the McMath-Pierce (McMP) solar telescope, a 10-arcsec square image slicer, and the McMP stellar spectrograph. They obtain sodium images that are 10 arcsec square with 1-arcsec pixels. Since 1997, they have accumulated approximately a thousand of these images covering a nearly complete range of true anomaly angles. The reason for collecting so many images lies in the fact that the sodium distribution over the planetary surface varies with time, and is usually different between the dawn and dusk hemispheres. They expect that analysis of these variations will lead to a better understanding of the processes that govern the interaction of the space environment with planetary surfaces. Figure 19 shows four sodium images that represent the most common kinds of sodium distribution. Since sodium distributions near the dawn terminator are usually different from the distributions near the dusk terminator, we have labeled the terminator side of each image as dusk or dawn. Figure 19a shows limb brightening, resulting from an approximately uniform distribution of sodium vapor in the Mercury atmosphere. Figure 19b shows dawn-side enhancement of sodium, where the dawn terminator is viewed. As the Sun rises, sodium that has condensed on the cold dark side of the planet is warmed, and evaporates into the atmosphere, leading to excess sodium near the dawn terminator. Figures 19c and 19d show northsouth asymmetries, where excess sodium is seen in either the northern hemisphere (Figure 19c) or the southern hemisphere (Figure 19d).

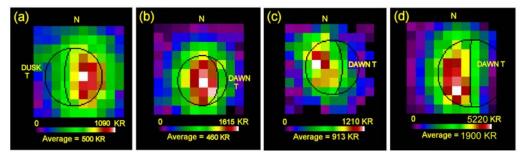
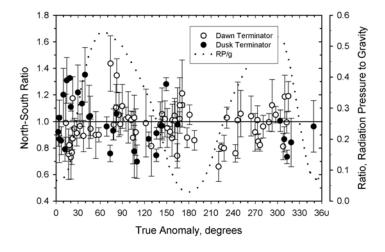
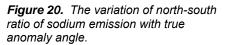


Figure 19. Example distributions of sodium on the surface of Mercury. Figure 19a is a limb-brightened image, as expected for a uniform distribution of sodium. Figure 19b shows sodium emission extending to the dawn terminator, and Figure 19c and 19d show northern and southern hemisphere excess sodium, respectively.

The simplest quantity that we can use to characterize the distribution patterns illustrated in Figure 19 is the ratio of the total sodium intensity from one hemisphere to its opposite. We calculated north-south and east-west ratios, using the brightest pixel in the surface reflection image as the center of the image. The north-south ratios are plotted against true anomaly angle in Figure 20.

Each data point represents the average of ten or more images taken on one day, with a standard deviation of about ten percent. For symmetric distributions, such as seen for limb brightening in Figure 19a, the ratio should be approximately unity. In fact, most of the ratios are near unity. However, about a third of the ratios show significant excess sodium either in the north or south, with southern excess predominating over northern excess. There does not seem to be any relation to the intensity of radiation pressure or whether the dawn or dusk terminator is viewed. Rather, the excess sodium ratios appear to be random. Potter and colleagues suggest that excess north or south sodium emissions are the result of sputtering of sodium from surface rocks by direct impact of the solar wind on the surface, occurring at random intervals related to solar weather conditions. Sarantos et al. (2001, *Planet. Space Sci.*, **49**, 1629) have shown that open field lines can connect with Mercury's surface at high latitudes, and their number and hemispheric locations depend on values of the IMF. Equally important is the fact that heavy stripped ions in the solar





wind are extraordinarily efficient sputtering agents, as shown by Shemansky (2003, AIP Conf. Proc., 63, 687).

The east-west ratios showed some interesting features. Instead of east-west ratios, it is more meaningful to look at the ratios in terms of the equivalent terminator-limb ratios, so as to clearly discriminate between dusk and dawn terminator effects. The plot of terminator-limb ratios against true anomaly angle is shown in Figure 21.

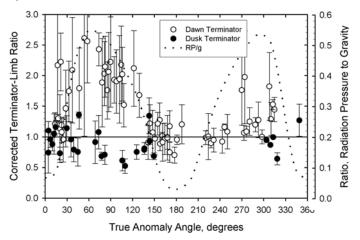


Figure 21. The variation of terminatorlimb ratio with true anomaly angle.

The ratio for the dawn terminator rises to values over 1.5 for true anomaly angles less than 150 degrees. There is a rough correlation with the magnitude of radiation pressure. Potter and colleagues suggest that this is the result of a combination of effects: Condensed sodium evaporates at the dawn terminator, and radiation pressure prevents its spread towards the sub solar point, leading to high values of the terminator-limb ratio. For larger true anomaly angles, the effect disappears, possibly because radiation pressure is less effective on the inward leg of the orbit (true anomaly angles greater than 180 degrees). The terminator-limb ratios where the dusk terminator is in view are mostly less than unity, as expected, and as illustrated in Figure 19a.

Potter and colleagues believe that sodium distribution data support the concept that interaction of the Mercury surface with the solar wind is a significant process on Mercury. Their data also support the existence of the dawn enhancement observed by Sprague *et al.* (1997, *Icarus*, **129**, 506), but its variation with true anomaly angle presents some unexplained features.

5 BRIDGES TO THE FUTURE

5.1 Kitt Peak

5.1.1 NSO Array Camera (NAC)

The ATST will be an all-reflecting, open solar telescope; currently the closest analogy is the NSO/Kitt Peak McMath-Pierce (McMP) telescope. The all-reflecting design of the McMath-Pierce gives it access to the entire solar spectrum that is transmitted through the Earth's atmosphere. Exploring the infrared parts of this spectrum is a high priority for NSO, and the wavelength range from 1,000-5,000 nm is the focus of the new NSO Array Camera program. The NAC is a closed-cycle cooled, InSb 1024 \times 1024 pixel camera and will obtain images, spectroscopy and polarization data in the 1,000-5,000 nm window. The NAC will replace the aging NSO Near Infrared Magnetograph (NIM) instrument, and will have lower read noise, faster read-out, and 16 times more pixels.

In 2005, the NAC was delivered and tested at the McMP telescope at Kitt Peak. Intensity spectroscopy was completed at 1083, 1565, 2312 and 4666 nm. A sample spectrum, taken in July 2005, showing the Zeeman splitting in a sunspot of the Fe I g=3 1565 nm absorption line is shown in Figure 22. Science data were taken of an X2 flare during September 2005 in the 1083 nm He I line; the line showed very strong emission during the flare. Two shared-risk observing runs collected data of the second overtone CO absorption spectra at 2312 nm. Finally, using an old filter from the NIM instrument, sample CO spectra at 4666 nm were taken using the single-read mode of the NAC and very short (25 micro-second) exposures. New cold filters for the 4000-5000 nm spectral region will be purchased to facilitate future science observations at these thermal wavelengths.

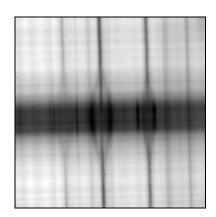


Figure 22. The first He I 1083 nm limb spectrum from the NSO Array Camera.

In the immediate future, the NAC will be used with a new near-IR

polarimeter to obtain polarization spectra from 1000-2500 nm. The components for this polarimeter are in-hand at NSO and currently being tested. In the next few years, an effort will be made to develop solar polarimetry in the 3000-5000 nm wavelength region. There are several promising spectral lines in this region, which will produce the most sensitive magnetic diagnostics of the solar photosphere, chromosphere and corona. The NAC, in combination with the McMP, will provide a unique opportunity to study these new lines.

The NAC system is also planned to be a bridge to the Advanced Technology Solar Telescope near-infrared instrumentation. The NAC dewar is flexible, with plenty of internal space available, and can accommodate upgrades for use with the ATST first-light instrumentation. The scientific discoveries that will come from the NAC observing runs during the next few years will drive near-infrared science programs at the ATST.

5.1.2 Seeing Improvement

Tests of potential improvements to the telescope seeing have been conducted during the last several years, including fans blowing air across the image-forming mirror, which is heated by the incoming sunlight. The wavefront sensor in the adaptive optics system has also revealed other sources of telescope seeing such as

the interface between the telescope and the observing room. Appropriate changes have been made to improve the internal seeing.

It is believed that installing fans similar to what is used at European Southern Observatory's New Technology Telescope facility to flush air across its primary mirror will reduce the seeing at the McMath-Pierce #2 mirror. Preliminary air flushing tests have been conducted with the McMath-Pierce 0.9-m West Auxiliary telescope. Knife-edge testing showed blowing air across the #2 mirror affected the seeing layer. The tests demonstrated a need for greater flow volume. Further tests are expected in 2006 with full implementation on the main telescope as resources allow.

5.1.3 Adaptive Optics (AO)

The infrared adaptive optics system at the McMath-Pierce telescope is now in routine use for scientific observations at the main spectrograph. The optical bench configuration has proven to be extremely flexible and has been used to feed the corrected beam to 2-D IR imagers as well as to the spectrograph's input slit. Spectral imaging is achieved by scanning the final beamsplitter using a stepper motor controlled translation stage. This moves the corrected image plane across the spectrograph slit. Most infrared observing runs now routinely request the adaptive optics system. The system can be used with any high-contrast feature smaller than the wavefront analysis camera's sub-aperture field of ~20 arcsecond field. The AO has a special 1-D correction mode for solar limb observations.

Several improvements have been made to the system over the past year. The AO system now has the capability to auto guide the telescope. The integration time of the wavefront camera can be increased for use with fainter, non-solar objects. By increasing the integration time as well as changing some of the system's bench optics, the system has been successfully demonstrated on the planet Mercury as well as stars down to magnitude 2.6. Fully AO-corrected observations of Mercury and other solar system objects are of high interest to future US and European space missions. Full documentation as well as the source code for all of the software is available on the Web.

The predecessor to the full AO system is an image stabilizer based on the same high-speed piezoelectric tiptilt correction mirror and wavefront camera used on the AO bench. The image stabilizer is still in high demand for planetary and 12-micron solar observations. Seeing at 12 microns is typically lower than the diffraction limit of the McMath-Pierce, making full AO unnecessary. Recently, the technique of increasing integration time on the wavefront camera has been adapted from the AO bench, allowing image stabilized IR observations of Saturn. With the incorporation of an image intensifier, the image stabilizer has been successfully demonstrated on objects down to 7th magnitude.

5.1.4 McMath-Pierce Telescope Control System TCS)

A new telescope control system is needed to ensure that the McMath-Pierce facility remains competitive and maintainable. Funds for this upgrade have been identified in the NSO budget, and the project is expected to proceed in 2006. Currently a detailed technical request for quote (RFQ) has been written and will be distributed to vendors for bids. The new TCS is expected to replace the aging McMP control system, which is still using a PDP-11. The new TCS will provide a scripting capability for taking timesequence observations, it will integrate the instrument control and the adaptive optics and telescope control, and will be composed of off-the-shelve components for easy maintenance.

5.1.5 Integral Field Unit (IFU) for the McMath-Pierce Telescope

A grant from the NSF Advanced Technology Instrumentation (ATI) program is funding development of a state-of-the-art all-reflective image slicer integral field unit. The IFU is being developed for AO-corrected infrared observations with the McMath-Pierce vertical spectrograph. Deqing Ren (NJIT) and Christoph Keller are co-investigators on this project that will divide a $6.25" \times 8"$ 2-D field into 25 slices to produce a 200" long slit with a width of 0.25" for diffraction-limited spectroscopy and polarimetry in the IR. The IFU is designed to be used over the 0.8 - 5.0 micron range and is optimized for 1.56 micron observations of the strongly Zeeman split (g = 3) Fe I line. The IFU will be enclosed in a ~1.2 m × 0.3 m x 0.3 m box that mounts in the optical beam between the current AO system and spectrograph slit.

The optical design was completed in 2005. A vendor has been contacted about manufacturing the slicer mirror array. The pupil and slit mirror arrays will be made after the purchase order for the slicer mirror array is finalized. In 2006, all mechanical parts will be machined, assembled and tested at the NJIT optical laboratory. The IFU assembly is scheduled to be shipped to Kitt Peak to begin testing at the telescope in the second half of 2006.

5.2 Sacramento Peak

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

SPINOR is a joint High Altitude Observatory (HAO)/NSO program to upgrade the existing Advanced Stokes Polarimeter (ASP) at the Dunn Solar Telescope. The ASP has been the premier solar research spectro-polarimeter for the last decade. Its ability to explore new spectral lines and to observe in multiple lines simultaneously is still unique. The ASP wavelength range, however, is restricted to the visible, limiting its ability to sample new solar diagnostics, and its hardware is becoming outdated and difficult to maintain. The HAO received National Center for Atmospheric Research (NCAR) funding to build SPINOR, which would extend the wavelength of the ASP from 750 nm to 1600 nm with new cameras and polarization optics, provides improved signal-to-noise and field-of-view, and replaces obsolete computer equipment. Software control of SPINOR will be brought into the DST control system as opposed to the stand-alone ASP. SPINOR will augment capabilities for research spectro-polarimetry at the DST and extend the lifetime of state-of-the-art research spectro-polarimetry at the DST for another decade. During May 2005, a first test run with many elements of SPINOR was made. Commissioning is currently planned for 2006.

5.2.2 Charged Couple Device (CCD) Upgrade

The primary goal of the CCD project was to provide a reliable and stable data acquisition system for the Dunn Solar Telescope. Additional benefits include: providing interchangeable camera-computer configurations on a day-to-day basis, and easing the required maintenance effort of the entire camera system. This upgrade was completed during FY 2005.

5.2.3 Evans Solar Facility (ESF)

The Evans Solar Facility provides a 40-cm coronagraph as well as a 30-cm coelostat. The Evans coronagraph is the most thoroughly instrumented in the world. The ESF 40-cm coronagraph currently is used primarily by NSO's USAF partners, while the coelostat is used in the NSO Ca II K-line monitoring program. After six months of simultaneous operations with SOLIS, the ESF K-line program will be closed.

SOLIS also replaces the spectroheliogram capability of the ESF. The Air Force group provides funding for a part time observer and provides NSO with some funds for minimal maintenance. The High Altitude Observatory has expressed interest in using the coronagraph for a visible and IR coronal polarimeter, building on the recent tantalizing observations of coronal magnetic fields. This new instrumentation would provide core capabilities for the next generation of ground- and space-based coronal telescopes.

6 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. Scientists at each site have responsibility for the local educational and public outreach program, with additional support provided by other members of the scientific and support staff and, during the summer, by resident students. In addition to conducting public relations and outreach as part of the ATST program, Educational and Public Outreach (EPO) Officer Dave Dooling coordinates the ATST educational and public outreach (EPO) efforts with that of the NSO and other ATST partners. What follows is a summary of educational and public outreach activities during FY 2005. Detailed descriptions of activities appear in the NSO FY 2005 Quarterly Reports, which are posted at <u>http://www.nso.edu/general/docs/</u>.

Dave Dooling developed new outreach concepts during the ATST construction phase proposal process. The concepts are to be developed for delivery through, and in support of, existing EPO activities (TLRBSE, Project ASTRO, etc.), rather than developing new channels. These activities were to be defined during calendar year 2005 and are being presented for comments by the NSO staff. The projects will be developed as a combination of portable museum exhibit and classroom activity:

- *Max 2008* is a program with activities focused on the Cycle 24, which starts in 2007-2008, the International Heliophysical Year in 2007, and the centennial of Hale's discovery of magnetism in sunspots in 1908. Significant work was done during 2004 on defining a museum exhibit on solar magnetism as part of Max 2008.
- *The Goldilocks Star* (formerly called *Other Suns for Other Worlds*), a program to connect nighttime astronomy with the Sun, specifically by exploring concepts for determining what stars would be most hospitable for life.
- *The Sun on Wheels*, an education van outfitted to take current and future educational materials to schools, including telescopes for students to observe the Sun.

6.1 Educational Outreach

6.1.1 Summer Research Assistantship (SRA) Programs, including Research Experiences for Undergraduates (REU) and Research Experiences for Teachers (RET)

Over 700 announcements about the Summer 2005 Research Experiences for Undergraduates Program at NSO were sent to astronomy, physics, engineering, mathematics, and natural science departments throughout the US and Puerto Rico. An announcement about the NSO Summer 2005 Research Experience for Teachers (RET) Program was widely distributed electronically via the National Astronomy List Serves, Arizona Physics Teachers List Serves and the Arizona Science and Math Education Center; announcements were also sent to schools districts throughout New Mexico and in Tucson. The NSO 2005 Summer Outreach Program supported eight undergraduates and four high school teachers under the NSF-funded

REU and RET programs, respectively; there were twelve graduate SRA's, of which three were PhD candidates doing ATST-related theses, four were sponsored by staff grant funds, two were Air Force Space Scholars, and one was from the High Altitude Observatory. NSO also exhibited at the annual convention of the American Indian Science and Engineering Society (AISES) and advertised the REU/RET program in *Winds of Change*, the AISES magazine.



Figure 23. NSO 2005 REU, RET, and Summer Research Assistantship (SRA) Program participants. From the back row eft: Alexei Pevtsov (Staff Mentor), K.S. Balasubramaniam (Staff Mentor), Paul Anzel (REU, Rice Univ.), Patrick Maloney REU, Carleton College), Kyle Momenee (REU, Milwaukee School of Engineering), Christopher Beaumont (REU, Calvin college), Douglas Mason (REU, Univ. Southern California), Michael Sinclair (RET, Kalamazoo Math & Science Ctr.), Indrea Allen (Florida Inst. Technology), Vera Dillard-Pape (RET, Bernalillo Middle School, NM), Nina Karachik (Grad SRA, Tashkent State Univ., Russia), Lokesh Bharti (Grad SRA, Mohanlal Sukhadia Univ., India). Front row from left: Cheryl Innette Kincaid (Grad AF Scholar, North Texas State Univ.), Yu Chen (REU, Skidmore College), Hyun Kyong An (Grao SRA, Univ. Alabama-Huntsville), and Rachel Hock (REU, Osford Univ./Wellesley). Missing from photo are Mark Calhoun RET, Sabino High School, Tucson), Jim Renshaw (RET, St. Pius High School, Albuquerque), Amel Zaatri (Grad SRA, JSTHB, Algeria), Fredrich Wöger (Grad SRA, Kiepenheuer Institute, Germany), Justin Edmonson (Grad SRA, Univ. Michigan), Walter Allen (Grad AF Scholar, Howard Univ.), and Brian Harker-Lundberg (Grad SRA, Utah State Univ.)

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

During the fall quarter, Frank Hill and Claude Plymate, in collaboration with Connie Walker (NOAO), worked with teachers and students from Graves County High School in Mayfield, Kentucky and Linwood Holton Governor's School in Abingdon, Virginia on observing runs at the McMath-Pierce Solar Telescope (McMP), using the Amber infrared array to measure Zeeman splitting and magnetic fields in the Fe I 1.5-micron line. A substantial amount of data was collected and analyzed by the students. Another similar observing run was conducted for one week at the McMP in June 2005, NSO co-hosted a week-long

observing run at the McMath-Pierce Solar Telescope as part of the NOAO TLRBSE summer program, involving three high-school teachers and one community college science instructor, on studying magnetic active region mapping using a 1.5-micron magnetograph. Frank Hill implemented a software package to allow the teachers to reduce and analyze McMath-Pierce IR spectra. The teachers were also provided with copies of the NSO designed RASL/DASL (Research in Active Solar Longitudes/Data and Activities for Solar Learning) software and workbooks as part of the TLRBSE program.

6.1.3 Project ASTRO

Throughout the year, Irene González Hernández and Kerri Donaldson-Hanna worked with students at Esperanza Elementary School in South Tucson and Richey Elementary and Middle School, respectively, and Roberta Toussaint worked with students at the Tucson/Robison Elementary School. NSO hosted the annual Project ASTRO Teacher/Astronomer Workshops at Sacramento Peak, in conjunction with the New Mexico Museum of Space History, in October 2004 and September 2005.

6.1.4 Further Undergraduate and Graduate Education

NSO continues with its strong commitment to supporting graduate education and attracting students to solar physics research. New Jersey Institute of Technology (NJIT) graduate student Jose Marino continues work towards his PhD under the supervision of Dr. Thomas Rimmele. Marino is developing techniques for using the AO wavefront sensor to obtain the instantaneous point spread functions of AO-corrected images so they can be fully restored. Dr. Matt Penn continued to mentor University of Arizona undergraduate student Sarah Jaeggli, who was a former REU student (2003) and worked with Dr. Penn on data from the NSO/CSUN IR camera at the McMath-Pierce. Jaeggli graduated in May 2005 and has started graduate school this fall at the University of Hawaii Institute for Astronomy with the intention of doing a PhD thesis involving solar infrared instrumentation.

Dr. Joel Mozer taught an introductory course in Astronomy, "A Survey of the Universe," during the spring semester at New Mexico State University (NMSU)-Alamogordo, and Dr. Alex Pevtsov taught a graduate course on "Observational Astrophysics" during the fall and winter quarters at Montana State University in Bozeman.

On March 19-21, members of the NSO staff (Mark Giampapa, Frank Hill, Claude Plymate, Matt Penn, Bill Sherry) participated in the LAPLACE-University of Washington (UW), Seattle exchange that involved a visit to Kitt Peak by 14 graduate students from the UW astrobiology program along with members of the Life and Planets Astrobiology Center (LAPLACE) of the University of Arizona. The graduate students represented a broad range of disciplines in the life and physical sciences, and engineering. During their three days on the mountain, the students participated in demonstration observing exercises in order to gain an understanding of how astronomical data relevant to goals in astrobiology are obtained, reduced and analyzed. At the McMath-Pierce Solar Telescope, the grad students obtained infrared spectra of sunspots and measured umbral field strengths based on the observed Zeeman splitting of a magnetically sensitive Fe I line at 1.56 microns. In addition, they saw Ca II H and K spectra acquired for active regions in the vicinity of the spot, similar to the kind of spectra obtained at the nighttime telescopes for active solar-type stars. The solar observations were interspersed with presentations on solar-terrestrial interactions, solar-stellar activity, and helioseismology.

6.1.5 Other Educational Outreach

In 2004, the NSO joined as a co-investigator with the University of Arizona Lunar and Planetary Laboratory (LPL) in the submission of a proposal to a new NSF program entitled "Faculty Development in the Space Sciences." This novel program, administered by the Atmospheric Sciences Division of the NSF, offers the opportunity to compete for the funds required to initiate and sustain for a five-year period new tenure-track faculty positions in the space sciences, solar physics and other related fields. The joint LPL/NSO proposal was selected for funding by the NSF, and in 2005 LPL started advertising the availability of a new faculty position in solar physics. The NSO is actively involved in the recruiting process and has a representative on the LPL search committee for this position. The location of the NSO-Tucson site on the University of Arizona campus can facilitate and enhance the collaborative opportunities available to a new solar physics faculty member of the university community.

Throughout the year, scientific staff at both sites gave talks at local elementary schools and organized star parties for students, parents and teachers. NSO officials from Sac Peak and Tucson also assisted with city and regional science fairs in their areas. Ramona Elrod and Jackie Diehl represented NSO with an exhibit at the annual National Science Teachers Association Convention in Dallas. Dave Dooling mentored students at Cloudcroft High School who were studying astronomy for the Science Olympiad, and administered the regional test.

For the International Year of Physics, NSO developed a poster highlighting how Einstein predicted certain relativistic effects would be caused by the Sun (precession of Mercury, bending of light), and how Einstein's theories enhanced our knowledge of the Sun (mass-energy equivalence and fusion, spectral absorption lines and the photoelectric effect).

Dooling attended the Astronomical Society of the Pacific conference on *EPO: The Emerging Profession*, held in September in Tucson.

6.2 Public Outreach

6.2.1 Sunspot Visitor Center

A continuing effort was planning for a community solar system centered on the Sunspot Astronomy and Visitor Center. The overall objective is to learn about the need for solar studies by providing a 16-foot walkthrough model of the Sun as the destination in a 16-mile trip across the solar system starting in Cloudcroft. Signs and scaled planet models will be placed at appropriate locations along the Sunspot Scenic Byway (NM Dr. Don Neidig is the principal 6563). investigator. Agencies solicited as partners include the Cloudcroft Chamber of Commerce, Space Museum in Alamogordo, the Las Cruces Museum of Natural History, the state Scenic Byways office, and the Otero County Tourism

Sunspot Astronomy & Visitor Center Summary of Visitors and Tours (12 Months Ending 09/30/05)				
Group/Program	No. of Visitors			
General Public Tours (Visits to Center and				
Self-Guided Tours)	14,119			
Guided Public Tours:				
- School Groups K-12	384			
- Special Tours 582				
Total Visitors 15,085				

Council. The concept was refined and plans developed for starting with two $6' \times 8'$ transparencies in the Visitor Center. These will provide images of the planets to the same scale as planned for the model and a cutaway image of the Sun, also to scale.

The Sunspot Visitor Center neared completion on the heliostat viewer, which has been built up from the original helioseismology telescope that operated at the South Pole in the 1980s. It is located outside the Visitor Center and projects an image into the building. Preliminary operations of the viewer have begun. Software problems are nearing resolution and routine observing was to start in October.

During the year, the Visitor Center hosted approximately 15,000 visitors. Another 966 visitors toured the NSO grounds (open sunrise to sunset) without entering the Visitors Center. Public lectures, and guided tours were held daily at 2 pm during the summer months when RET and REU interns were available.

6.2.2 Other Public Outreach

Sunspot continued a series of quarterly public lectures with the Lodestar Planetarium at the New Mexico Museum of Natural History in Albuquerque. Lecturers were: Han Uitenbroek in December, and Alexei Pevtsov in March. NSO also set up exhibits at the southern regional New Mexico State Fair in Las Cruces and Astronomy Day in Albuquerque.

6.2.3 External Coordination

In January 2005, three NSO Summer 2004 REU students, Joel Lamb, Michelle McMillan, and Stuart Robbins, presented poster papers at the 205th Meeting of the American Astronomical Society in San Diego.

In June 2005, NSO staff and NSO/REU students attended the 37th Solar Physics Division (SPD) meeting of the American Astronomical Society in New Orleans, held jointly with the AGU. 35 poster papers and talks were presented by NSO staff and resident partners. Five NSO REU students, Frances Edelman (2004), Heidi Gerhardt (2004), Statia Luszcz (2004), Stuart Robbins (2004), and Sarah Jaeggli (2003) presented poster papers. NSO was an exhibitor at the SPD meeting, with a double booth featuring poster displays and handouts on the Observatory's major projects and initiatives.

Scientists from around the world gathered in Sunspot, New Mexico, 18-22 October 2004, for the NSO 22nd annual international science workshop on "Large-Scale Structures and Their Role in Solar Activity," and on 18-22 July 2005 for the 23rd NSO workshop on "Solar MHD: Theory and Observations — A High Spatial Resolution Perspective," in honor of Bob Stein.

NSO continued its support of the Southwest Consortium of Observatories in Public Education (SCOPE) at semi-annual meetings in Sunspot (November) and Mt. Hopkins, AZ (April), and with materials for a new poster.

6.3 Media and Public Information

6.3.1 Press Releases and Image Releases

Major stories during the year were the confirmation of Haleakalā as the preferred site for ATST and the start of the Environmental Impact Statement process for ATST. NSO also produced obituary releases upon the passing of Keith Pierce and Richard Dunn. Additional releases were produced on new images

made with the upgraded adaptive optics system at the Dunn Solar Telescope and on the Virtual Solar Observatory.

	PRESS RELEASES ISSUED IN FY 2005
•	October 5, 2005: "Dr. Richard B. Dunn Passes Away"
	(<u>http://www.nso.edu/press/Dunn.html</u>)
٠	October 4, 2005: "Adaptive Optics Produces Ultrasharp Images of Sunspot"
	(http://www.nso.edu/press/DALSA/)
٠	March 23, 2005: "Dr. A. Keith Pierce Passes Away"
	(http://www.nso.edu/press/pierce_rev23mar05_obit-post.pdf)
٠	January 6, 2005: "Haleakala, HI, Endored for the Advanced Technology Solar"
	Telescope" (http://www.nso.edu/press/ATST/ATST_FinalSite.html)
٠	December 14, 2004: "Virtual Solar Observatory Now Available For 'One-Stop Data
	Shopping" (<u>http://www.nso.edu/press/vso.html</u>)
٠	October 25, 2004: "Haleakala, Hawaii, Recommended for the Advanced
	Technology Solar Telescope"
	(http://www.nso.edu/press/ATST/ATST_RecommendedSite.html)
٠	October 15, 2004: "Think Big' is Plan at Solar Physics Conference (Large-Scale
	Structures Conference at Sunspot)" (<u>http://www.nso.edu/press/thinkbig.html</u>)

6.3.2 Special Information Products

The adaptive optics Web pages were rewritten in 2005. An extensive research effort was completed to survey the status and capabilities of high-resolution optical solar telescopes in the context of science requirements identified for ATST (*The Sun@22 km*). This is planned as a white paper and as a poster for AAS/SPD or SPIE in 2006. A quarterly ATST Newsletter was initiated with first issues in January and April 2005. The third and fourth issues for calendar year 2005 are being combined, and production in 2006 will be synchronized with the *NOAO/NSO Newsletter*.

APPENDIX A

OBSERVING AND USER STATISTICS

In the 12 months ending 30 September 2005, 71 observing programs, which include 8 thesis programs, were carried out at NSO. Associated with these programs were 69 scientists from 39 US and foreign institutions.

NSO Observing Programs by Type (US vs Foreign)				
12 Months Ending Sept. 2005	Nbr	% Total		
Programs (US)	53	75%		
Programs (non-US)	10	14%		
Thesis (US)	3	4%		
Thesis (non-US)	5	7%		
Total Number of Unique Science P	rojects* 71	100%		

Users of NSO Facilities by Category						
	Visitors Staff					
	US	Non-US	Total	% Total		
PhDs	50	19	69	75%	15	
Graduate Students	4	10	14	15%	0	
Undergraduate Student	2	0	2	2%	0	
Other	6	1	7	8%	13	
Total Users	62	30	92	100%	28	

*Includes observing programs conducted by NSO/NOAO

staff scientists.

Institutions Represented by Visiting Users**					
US Non-US Total % Total					
Academic	18	6	24	62%	
Non-Academic	12	3	15	38%	
Total Academic & Non-Academic	30	9	39	100%	

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

US Institutions (24)

California State University, Northridge Carnegie Institution of Washington College of William & Mary Dickinson College East Carolina University High Altitude Observatory, NCAR, Boulder Lockheed Martin Solar & Astrophysics Lab Maria Carillo High School, Santa Rosa, CA McEwen High School, McEwen, TN Montgomery High School, Cunningham, TN NASA Jet Propulsion Laboratory NASA/Goddard Space Flight Center NASA/Langley Research Center NASA/National Research Council

Foreign Institutions (15)

ETH Zurich, Institute for Astronomy INAF - Arcetri Astrophysical Observatory Instituto de Astrofisica de Canarias Kiepenheuer Institut fuer Sonnenphysik, Germany Lomonosov Moscow State University, Russia Natnl. Research Inst. of Astronomy & Geophysics, Egypt Observatoire de Paris, Section de Meudon, France

Number of Users by Nationality						
Canada	3	Mexico	1			
Egypt	1	Norway	1			
France	2	Russia	1			
Germany	2	Spain	4			
Ireland	3	Switzerland	5			
Italy	7	United States	90			

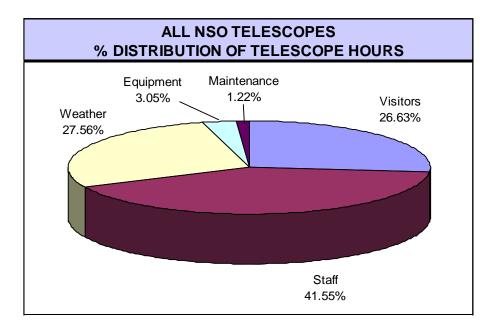
New Jersey Institute of Technology/Big Bear Solar Observatory Sabino High School San Francisco State University Southwest Research Institute, San Antonio St. Pius X High School, Albuquerque Stanford University University of Arizona University of Arizona University of Hawaii University of Maryland University of Washington, Seattle University of Wisconsin, Madison US Air Force/Philips Lab (USAF/PL/GSS) Windward Community College

Observatoire de Midi Pyrenees, Toulouse Observatoire de Pic-du-Midi, France Queens University, Belfast Universidad de Monterrey, Mexico University of Oslo University of Calgary University of Rome University of Waterloo

FY 2005 USER STATISTICS – TELESCOPE USAGE AND PERFORMANCE DATA

In the fiscal year ending 30 September 2005, 26.6% of the total available telescope hours at NSO/Sacramento Peak and NSO/Kitt Peak went to the observing programs of visiting principal investigators; 41.6% were devoted to those of NSO scientists. Scheduled maintenance (including instrument tests, engineering, and equipment changes) accounted for 1.2% of total allotted telescope hours.

Total "downtime" (hours lost to weather and equipment problems) for NSO telescopes was 30.6%. Almost all of these lost observing hours were due to bad weather (27.6%), with 3.0% lost to equipment problems.



NSO TELESCOPES Percent Distribution of Telescope Hours (Scheduled vs. Downtime) October 1, 2004 - September 30, 2005								
Telescope		% Hours Used By:		s Lost To:	% Hrs. Lost To:			
	Available	Visitors ^a	Staff	Weather	Equipment	Scheduled Maintenance		
Dunn Solar Telescope/SP	3,634.0	25.5%	18.9%	42.8%	2.9%	9.8%		
McMath-Pierce*	3,610.5	26.6%	41.5%	27.6%	3.0%	1.2%		
KP Vacuum Telescope ^b	0.0	0.0%	0.0%	0.0%	0.0%	0.0%		
FTS Lab*	2,082.5	44.2%	1.7%	0.2%	13.5%	40.3%		
Evans Facility	1,057.5	27.1%	10.9%	55.9%	6.1%	0.0%		
Hilltop Dome	56.0	100.0%	0.0%	0.0%	0.0%	0.0%		
All Telescopes	10,440.5	26.6%	41.5%	27.6%	3.0%	1.2%		

^aIncludes synoptic programs for which all data are made available immediately to the public and scientific community at large. ^bThe KPVT was closed on 22 September 2003 to prepare for SOLIS. The KPVT will become the Kitt Peak SOLIS Tower (KPST). *Totals include both day and night hours. (All others are day only.)

FY 2005 USER STATISTICS – ARCHIVES/DATA BASES

NSO/SACRAMENTO PEAK

Combined Service User Demographics (NSO/SP)				
Demographic Group Requests Tra				
U.S. Science (.gov, .edu, .mil)	7.5%	11.7%		
Other U.S. (.com, .net, misc.)	70.3%	65.7%		
Foreign	20.1%	21.0%		
Unresolved	2.1%	1.5%		

FTP Archive Statistics

There were 754,755 successful user requests serving 8,353 distinct files to 24,314 distinct hosts. A total of 156.192 Gbytes were served, averaging 438.206 Mbytes per day.

FTP User Demograp	F1		
Demographic Group	Requests	Traffic	Produ
U.S. Science (.gov, .edu, .mil)	8.7%	17.4%	Realtime Ima
Other U.S. (.com, .net, misc.)	71.5%	63.7%	
Foreign	17.7%	17.8%	
Unresolved	2.1%	1.1%	Other

FTP Products (NSO/SP)					
Product	Requests	Traffic			
Realtime Images	8.3%	8.3%			
Corona Maps	90.1%	76.0%			
Staff Outgoing	0.9%	15.5%			
Other	0.7%	0.1%			

World Wide Web Statistics

There were 4,948,994 successful user requests serving 52,691 distinct files to 353,725 distinct hosts. A total of 138.632 Gbytes were served averaging 388.932 Mbytes per day.

WWW User Demographics (NSO/SP)					
Demographic Group Requests Traffic					
U.S. Science (.gov, .edu, .mil)	7.4%	5.3%			
Other U.S. (.com, .net, misc.)	70.1%	68.0%			
Foreign	20.4%	24.7%			
Unresolved	2.1%	2.0%			

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

WWW Products (NSO/SP)		
Product	Requests	Traffic
Realtime Images and Movies (ISOON, Other)	15.6%	22.0%
Other Images	8.3%	30.9%
General Icon and Background Images	24.9%	5.8%
Public Relations Pages	12.5%	6.3%
Press Releases	1.4%	4.2%
Telescope Home Pages	6.4%	3.1%
ISOON Project Images	3.6%	2.4%
SMEI Experiment & Data Pages	3.1%	3.5%
Adaptive Optics Pages	1.1%	5.3%
General Information	10.4%	7.0%
Staff Pages	2.3%	5.4%
Other	10.4%	4.1%

NSO/TUCSON

FTP User Demographics (NSO/Tuc)		
Demographic Group	No. of Users	%Total
U.S. Science (.gov, .edu, .mil)	390	18.04%
Other U.S. (.com, .net, misc.)	814	37.65%
Foreign	511	23.64%
Unresolved	447	20.68%
Total Users	2,162	100%

FTP Logins (NSO/Tuc)		
Demographic Group	No. of Logins	%Total
U.S. Science (.gov, .edu, .mil)	141,285	64.56%
Other U.S. (.com, .net, misc.)	11,941	5.46%
Foreign	38,769	17.71%
Unresolved	26,857	12.27%
Total Logins	218,852	100%

Gbytes of FTP & WWW Data Downloaded (NSO/Tuc)		
Demographic Group	Gbytes	%Total
U.S. Science (.gov, .edu, .mil)	1,462.85	88.8%
Other U.S. (.com, .net, misc.)	59.65	3.6%
Foreign	103.85	6.3%
Unresolved	21.12	1.3%
Total Gbytes	1,647.47	100%

FTP Products (NSO/Tuc)		
Demographic Group	No. of Products	%Total
U.S. Science (.gov, .edu, .mil)	1,699,512	91.31%
Other U.S. (.com, .net, misc.)	60,690	3.26%
Foreign	85,056	4.57%
Unresolved	15,972	0.86%
Total Products	1,861,230	100%

Product Distribution by Downloaded Files (NSO/Tuc)		
Product Type	No. of Files	%Total
GONG (Magnetograms, spectra, time		
series, frequencies)	1,745,596	93.8%
SOLIS/VSM	24,148	1.3%
KPVT (magnetograms, synoptic		
maps, helium images)	76,799	4.1%
FTS (Spectral atlases, general archive)	14,446	0.8%
Evans/SP Spectroheliograms (Ha,		
Calcium K images)	241	0.01%
Total Downloaded Files 1,861,230 100.0%		100.0%

Product Distribution by Downloaded Gbytes (NSO/Tuc)		
Product Type	Gbytes	%Total
GONG (Magnetograms, spectra, time		
series, frequencies)	1,502.22	91.2%
SOLIS/VSM	13.37	0.8%
KPVT (magnetograms, synoptic		
maps, helium images)	119.09	7.2%
FTS (Spectral atlases, general archive)	12.65	0.8%
Evans/SP Spectroheliograms (Ha,		
Calcium K images)	0.14	0.01%
Total Downloaded Files	1,647.47	100.0%

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

APPENDIX B

FY 2005 PUBLICATIONS October 2004 through September 2005

AuthorNSO StaffAuthorREUAuthorRETAuthorGrad StudentAuthorNon-REU Undergrad

The following is a partial list of papers published during FY 2005 by NSO staff, as well as papers resulting from the use of NSO facilities.

Refereed Publications (95)

Almeida, J. S. 2005, "Physical Properties of the Solar Magnetic Photosphere under the MISMA Hypothesis. III. Sunspot at Disk Center," ApJ, 622, 1292.

Altrock, R. C. 2004, "The Temperature of the Low Corona during Solar Cycles 21-23," Sol. Phys. 224, 255.

Bachmann, K. T., Maymani, H., Nautiyal, K., te Velde, V. 2004, "An Analysis of Solar-Cycle Temporal Relationships Among Activity Indicators, AdSpR, 34, 274.

Balasubramaniam, K. S., Pevtsov, A. A., Neidig, D. F., and Cliver, E. W. 2005, "Sequential Chromospheric Brightenings beneath a Transequatorial Halo Coronal Mass Ejection," ApJ, 630, 1160.

Basu, S. and Mandel, A. 2004, "Does Solar Structure Vary with Solar Magnetic Activity?" ApJ, 617, L155.

Beckers, J. M. 2005, "Sunspots, Gravitational Redshift an Exo-Solar Planet Detection," AcHA, 25, 285.

Benner, D. C., et al. 2004, "Air-Broadening Parameters in the υ_3 Band of ${}^{14}N^{16}O_2$ Using a Multispectrum Fitting Technique," J. Mol. Spectrosc. 228, 593.

Berger, T. E., ... **M. S. Giampapa**, et al. 2005, "The Magnetic Properties of an L Dwarf Derived from Simultaneous Radio, X-Ray, and H-Alpha Observations," ApJ, 627, 960.

Bloomfield, D. S. et al. 2004, "Wavelet Phase Coherence Analysis: Application to a Quiet-Sun Magnetic Element," ApJ, 617, 623.

Boyer, R. and Heristchi, D. 2004, "A Method for Rebuilding Blended Solar Lines, Sol. Phys., 223, 27.

Brown, L., et al. 2005, "Line Mixing in Self- and Foreign-Broadened Water Vapor at 6 μm," J. Mol. Structure, 742, 111.

Brown, L. R. 2005, "Empirical Line Parameters of Methane from 1.1 to 2.1 μm," J. Quant. Spectrosc. Rad. Transfer, 96, 251.

Burrows, A., **Dulick, M.**, et al. 2005, "Spectroscopic Constants, Abundances, and Opacities of the TiH Molecule," ApJ, 624, 988.

Butler, R. A. H., et al. 2005, "The Mid-Infrared Spectrum of Phosphine (PH₃) between 2.8 and 3.7 μm: Line Positions, Intensities, Assignments, and Single State Fits," J. Mol. Spectrosc. (in press).

Chou, D-Y, **Serebryanskiy, A.** 2005, "In Search of the Solar Cycle Variations of p-Mode Frequencies by Perturbations in the Solar Interior," ApJ, 624, 420.

Cremades, H., Bothmer, V. 2004, "On the Three-Dimensional Configuration of Coronal Mass Ejections," A&A, 422, 307.

Crisp, D., et al. 2004, "The Orbiting Carbon Observatory (OCO) Mission," Space Res., 34, 700.

de Toma, G., White, O. R., Chapman, G. A., Walton, S. R., Preminger, D., Cookson, A. M. 2004, "Solar Cycle 23: An Anomalous Cycle?," ApJ, 609, 1140.

DeForest, C., Elmore, D. F., **Bradford, M. P.**, **Elrod, J**., and **Gilliam, D. L.** 2004, "Stereoscopic Spectroscopy for Efficient Imaging and Magnetography," ApJ, 616, 600.

Del Moro, D. 2004, "Solar Granulation Properties Derived from Three Different Time Series," A&A, 428, 1007.

Devi, V. M., et al. 2004, "Self- and H₂-Broadened Width and Shift Coefficients in the 2 \leftarrow O Band of ¹²C¹⁶O Revisited," J. Mol. Spectrosc., 228, 580.

Devi, V. M., et al. 2005, "A Multispectrum Analysis of the υ_2 Band of H¹²C¹⁴N: Part I. Intensities, Broadening, and Shift Coefficients," J. Mol. Spectrosc., 231, 66.

Donea, A. C., Lindsey, C. 2005, "Seismic Emission from the Solar Flares of 2003 October 28 and 29," ApJ, 630, 1168.

Durrant, C. J., Turner, J. P. R., Wilson, P. R. 2004, "The Mechanism Involved in the Reversals of the Sun's Polar Magnetic Fields," Sol. Phys., 222, 345.

Eddy, J. A. 2005, "Solar Variability and Its Effects on Climate. Geophysical Monograph," Sol. Phys., 226, 187.

<u>Eydenberg, M. S.,</u> **Balasubramaniam, K. S.**, and Lopez Ariste, A. 2005, "PCA-Interpolation Methods for Inversion of Solar Stokes Profiles: I. Inversion of Photospheric Profiles," ApJ, 619, 1167.

Frohlich, C. and Lean, J. 2004, "Solar Radiative Output and its Variability: Evidence and Mechanisms," A&A Rev., 12, 273.

Goldman, A., et al. 2005, "Identification of Enhanced Absorption by ${}^{16}O_3$ Lines around 5 μ m in High-Resolution FTIR Solar Spectra," J. Quant. Spectrosc. Rad. Transfer, 96, 241.

Hase, F., et al. 2004, "Intercomparison of Retrieval Codes Used for the Analysis of High-Resolution, Ground-Based FTIR Measurements," J. Quant. Spectrosc. Rad. Transfer, 87, 25.

Hughes, S. J., Rajaguru, S. P., and Thompson, M. J. 2005, "Comparison of GONG and MDI: Sound-Speed Anomalies beneath Two Active Regions," ApJ, 627, 1040.

Jacquinet-Husson, N. et al. 2005, "The 2003 Edition of the GEISA/IASI Spectroscopic Database," J. Quant. Spectrosc. Rad. Transfer, 95, 429.

Jackson B. V.,...Keil, S. L., et al. 2004, "The Solar Mass-Ejection Imager (SMEI) Mission," Sol. Phys., 225, 177.

Killen, R. M., **Potter, A. E**., Sarantos, M., and Reiff, P. 2004, "Recycling of Ions in Mercury's Magnetosphere," HiA., 13, 66.

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Killen, R. M., Sarantos M., and Reiff, P. 2004, "Space Weather at Mercury," AdSpR, 33, 1899.

Knaack, R., Stenflo, J. O., Berdyugina, S. V. 2004, "Periodic Oscillations in the North-South Asymmetry of the Solar Magnetic Field," A&A, 418, L17.

Komm, R., Howe, R., Hill, F., González Hernández, I., and Toner, C. 2005, "Kinetic Helicity Density in Solar Subsurface Layers and Flare Activity of Active Regions," ApJ, 630, 1184.

Komm, R., Howe, R., Hill, F., González Hernández, I., and Toner, C. 2005, "Ring Analysis of Solar Sub-Surface Flows and Their Relation to Surface Magnetic Activity," ApJ, 631, 636.

Korzennik, S. G. 2005, "A Mode-Fitting Methodology Optimized for Very Long Helioseismic Time Series," ApJ, 626, 585.

Krieg, J. et al. 2005, "Sulphur Hexafluoride (SF₆): Comparison of FTIR-Measurements at Three Sites and Determination of Its Trend in the Northern Hemisphere," J. Quant. Spectrosc. Rad. Transfer, 92, 383.

Krivova, N. A., Solanki, S. K. 2004, "Effect of Spatial Resolution on Estimating the Sun's Magnetic Flux," A&A, 417, 1125.

Lawrence, J. K., Cadavid, A. C., and Ruzmaikin, A. 2004, "Principal Component Analysis of the Solar Magnetic Field I: The Asymmetric Field at the Photosphere," Sol. Phys., 225, 1.

Leka, K. D., Fan, Y., and Barnes, G. 2005, "On the Availability of Sufficient Twist in Solar Active Regions to Trigger the Kink Instability," ApJ, 626, 1091.

Liewer, P. C., Neugebauer, M., Zurbuchen, T. 2004, "Characteristics of Active-Region Sources of Solar Wind near Solar Maximum," Sol. Phys., 223, 209.

Lindsey, C. and Braun, D. C. 2005, "The Acoustic Showerglass. I. Seismic Diagnostics of Photospheric Magnetic Fields," ApJ, 620, 1107.

Lites, B. W. 2005, "Magnetic Flux Ropes in the Solar Photosphere: The Vector Magnetic Field under Active Region Filaments," ApJ, 622, 1275.

Livingston, W. C. 2005, "Glorious Visions: Colour and Slight in Nature," J. Br. Astron. Assoc., 115, 247.

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APPENDIX C

ORGANIZATIONAL PARTNERSHIPS

Through its operation of the entirety of US ground-based solar facilities freely available to US astronomers on a competitive peer-reviewed basis and its ongoing synoptic programs, NSO is clearly important to the solar community. In turn, NSO must work closely with the solar community and provide leadership to strengthen solar research, renew solar facilities and to develop the next generation of solar instrumentation. Some past examples of NSO meeting this responsibility include development of GONG and enhancement of the GONG network, development of solar adaptive optics in collaboration with NJIT and the Kiepenheuer Institute, development of multi-conjugate adaptive optics, development of infrared observing capabilities in collaboration with the University of Hawaii, California State University-Northridge, and NASA, and participation in the development of advanced Stokes polarimeters in collaboration with HAO. Table C-1 lists several ongoing joint projects and development efforts.

NSO sponsored several community workshops and forged an alliance of 22 institutions to develop a proposal for the design of the ATST and its instrumentation. NSO will continue to work closely with this group in leading the successful completion of the design and transition to construction of the telescope. A series of workshops on ATST science operations will begin this fall to provide guidance for developing a sound plan for exploiting the full potential of the ATST. NSO is developing partnerships with several European nations. Germany has sign an MOU with NSO for their participation in ATST and Italy, Spain and France are developing similar MOUs. Scientists from all of these countries have contributed to the ATST science definition, design and to the site survey.

NSO's strategic planning embraces the interdisciplinary nature and dual objectives of solar physics: in that it is both basic science and applied research. Likewise, NSO's relationships to its users reflect the diversity and richness of the communities they represent—solar and stellar astronomy, space plasma physics, solar-terrestrial relationships, space weather prediction, terrestrial atmospheric chemistry, and more. Table C-2 is a summary of the current partnerships that provide operational support. NSO's long-standing relationship with the US Air Force space science group will continue into the ATST era. The Air Force Office of Scientific Research (AFOSR) a desires to keep their basic solar research program collocated with NSO and has indicated that they will help purchase and polish the mirror for the ATST.

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

Table C-1. Joint Development Efforts		
Telescope/Instrument/Project	Collaborators	
Advanced Technology Solar Telescope	HAO, U. Hawaii, U. Chicago, NJIT, Montana State U.,	
	Princeton U., Harvard/Smithsonian, UC-San Diego, UCLA,	
	U. Colorado, NASA/GSFC, NASA/MSFC, Caltech,	
	Michigan State U., U. Rochester, Stanford U., Lockheed-	
	Martin, Southwest Research Institute, Colorado Research	
	Associates, Cal State Northridge	
Adaptive Optics	NJIT, Kiepenheuer Institute, AFRL	
Diffraction-Limited Stokes Polarimeter	НАО	
Spectro-Polarimeter for Infrared and Optical Regions (SPINOR)	НАО	
Narrowband Filters and Polarimeters	Arcetri Observatory, U. Alabama, Kiepenheuer Institute	
Synoptic Solar Measurements	USAF, NASA	
Fourier Transform Spectrometer	NASA	
Advanced Integrated Field Unit	NJIT	
IR Spectrograph and Cameras	U. Hawaii, Cal State Northridge	

Table C-2. Current NSO Partnerships		
Partner	Program	
Air Force Research Laboratory	Solar Activity Research at NSO/SP; Telescope Operations; Adaptive Optics; Instrument Development; 6 Scientists Stationed at NSO/SP; Daily Coronal Emission Line Measurements; Provides Operational Funding: \$450K-Base and Various Amounts for Instrument Development.	
NASA	Operational Funding for SOLIS: 2 Asst. Scientists; 1 Postdoctoral Research Asst.; 0.5 Instrument/Observing Specialist. McMath-Pierce: Support for Operation of the FTS; Upper Atmospheric Research. Funding for 2 GONG research fellows	
NSF Chemistry	FTS Support	

APPENDIX D

NSO MANAGEMENT ROSTER

Stephen L. Keil	NSO Director; ATST Project Director
Mark S. Giampapa	NSO Deputy Director; SOLIS Principal Investigator
Thomas R. Rimmele	ATST Project Scientist; Dunn Solar Telescope Program Scientist
Jeremy J. Wagner	ATST Project Manager
John W. Harvey	SOLIS Project Scientist
Carl J. Henney	SOLIS Facility Scientist
Valorie Burkholder	Project and Telescope Manager, Tucson/Kitt Peak
Stephen Hegwer	Project and Telescope Manager, Sacramento Peak
Frank Hill	GONG Program Scientist
Patricia Eliason	GONG Program Manager
Rex Hunter	Site Manager, Sacramento Peak

NOAO Managers Who Provide NSO Program Support

Karen Wilson	Associate Director for Administration and Facilities
David Sprayberry	Associate Director for Major Instrumentation
Doug Isbell	Assistant Director for Public Affairs and Educational Outreach
James Tracy	Controller
Steve Grandi	Manager, Computer Infrastructure Services (CIS)
Sandra Abbey	Manager, Human Resources
John Dunlop	Manager, Central Facilities