

NATIONAL SOLAR OBSERVATORY



NSO Annual Program Plan FY 2006

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MISSION

The mission of the National Solar Observatory is to advance knowledge of the Sun, both as an astronomical object and as the dominant external influence on Earth, by providing forefront observational opportunities to the research community. The mission includes the operation of cutting edge facilities, the continued development of advanced instrumentation both in-house and through partnerships, conducting solar research, and educational and public outreach.

NSO accomplishes this mission by:

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

RESEARCH OBJECTIVES

The broad research goals of NSO are to:

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

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I INTRODUCTION

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

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

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

The FY 2006 program outlined in this plan will continue to advance these long-range objectives. The plan presents in detail what NSO proposes to accomplish in FY 2006 with the \$10,131K budgeted by the NSF Astronomy Division for solar physics and with the additional funds received from NSO's partner organizations. The plan also discusses how the 2006 program supports the strategic goals of solar physics and areas where funding shortfalls are impacting the program. We outline areas where small funding increments would substantially enhance the NSF's return on its facilities by increasing community support and the science productivity of its major solar program, and where they would further benefit with implementation of ATST.

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

II NEW SCIENTIFIC CAPABILITIES

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

Figure II-1 shows the evolving roadmap of NSO facilities and major programs that support the solar physics community. During FY 2005, the ATST cost proposal was reviewed by an NSF panel. The reviewers thought the proposal was soundly costed in most areas, suggesting a few areas where the costs should be re-estimated to accommodate increased management oversight and increased commodity costs. Following the cost review, the project has rapidly progressed in several areas, including starting an environmental impact study (EIS) on Haleakalā. The project worked with the NSF to identify funds for continuing development in 2006 and 2007 to facilitate a smooth transition to construction in 2008. A minimum funding level of \$2M per year was identified to maintain progress. At higher funding levels, the final design reviews could be accelerated by engaging vendors in the final design of critical subsystems. AURA has subsequently adjusted the split between NSO and NOAO, reducing the \$2M to \$1.8M. This will impact our ability to engage vendors and perhaps retain key staff.

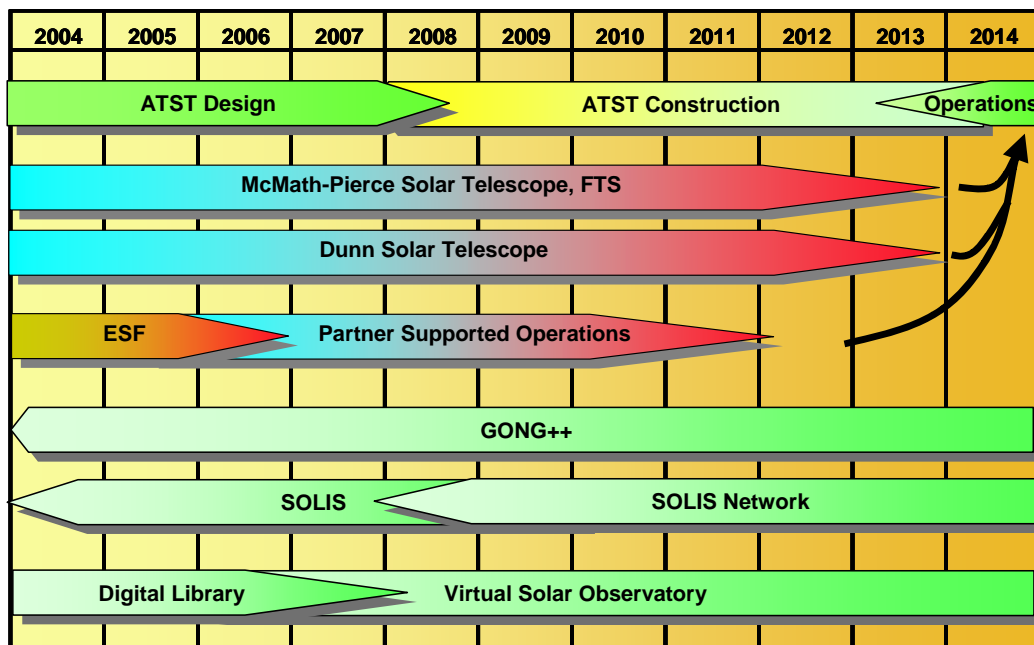


Figure II-1. Strategic Road Map of NSO Facilities.

The adaptive optics program has completed interfaces between the AO systems and the new diffraction-limited instrumentation. The program is currently focusing on multi-conjugate AO development and AO

design for the ATST. The SOLIS vector spectromagnetograph (VSM) has been operating in the magnetograph mode for the past two years and continues to provide line-of-sight magnetograms to the community via the NSO Digital Library and the emerging Virtual Solar Observatory (VSO). While SOLIS currently obtains full-disk vector maps there are still some calibration issues to resolve. The current plan is to complete final installation, debugging and cross-calibration of the other SOLIS instruments in the next few months, followed by commissioning of the entire SOLIS complex. GONG continued operating with its new high-resolution cameras, producing routine farside imaging and near-real-time magnetic field maps, which have applications for space weather prediction.

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

1 Initiatives

1.1 Advanced Technology Solar Telescope Project

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, 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.

Table II-1. Summary of Top-Level ATST Science Requirements	
Aperture	4 m
FOV	3 arcmin minimum; goal of 5 arcmin
Resolution	<i>Conventional AO Case:</i> Diffraction limited within isoplanatic patch for visible and IR wavelengths. <i>MCAO (upgrade option):</i> Diffraction limited over >1 arcmin FOV.
Adaptive Optics	Strehl (500 nm): >0.3 median seeing; >0.6 good seeing
Wavelength Coverage	300 nm - 28 μ m
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

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

1.1.1 ATST Science Working Group

Current membership of the Science Working Group can be found at <http://atst.nso.edu/swg/members.html>. 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.

1.1.2 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. See Appendix G for the ATST organizational chart.

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.

1.1.3 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.

1.1.4 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.

1.1.4.1 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.

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.

1.1.4.2 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

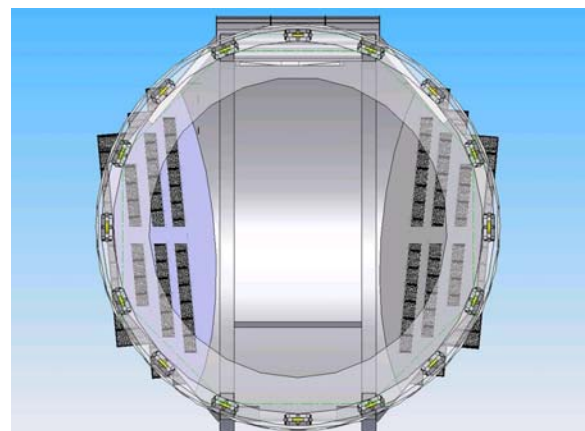


Figure II-2. A plan (top down) view of the enclosure carousel. The relatively minor 5-degree taper along the sides of the dome shown results in a significant increase in shaded surface area. It also provides room for ~11% larger vent gates for increased passive ventilation.

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.

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 ($R_0 > 12\text{cm}$) occur early in the day, mostly during periods of moderate wind ($\sim 5\text{ m/sec}$) 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.



Figure II-3. An artist's rendering of ATST at the primary site on Haleakalā. 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.

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.

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.

1.1.4.3 Support and Operation (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.

1.1.4.4 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.

1.1.4.5 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.

1.1.4.6 Software

The ATST software team successfully completed the Common Services and Telescope Control System preliminary designs in March 2005. Both systems were on a fast-track design and development 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.

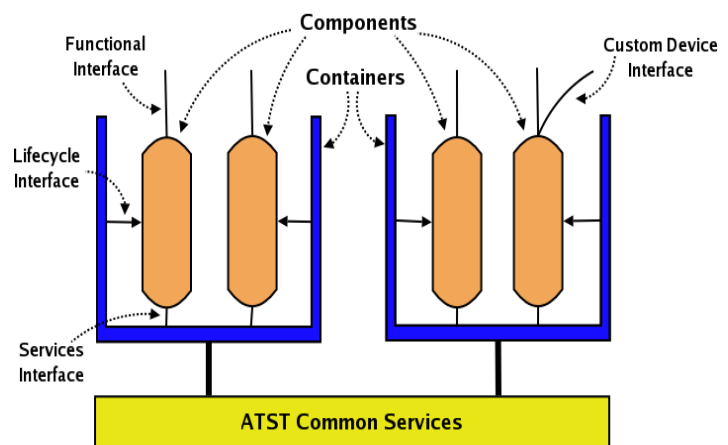


Figure II-4. The deployment of containers and their components in ATST systems.

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, the mount, enclosure, primary and secondary mirrors, feed optics, wavefront correction, and acquisition camera. In addition, the TCS provides 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 allows users to work in many reference frames. The TCS supports heliographic, helioprojective, heliocentric, sidereal, geocentric, and topocentric coordinate systems.

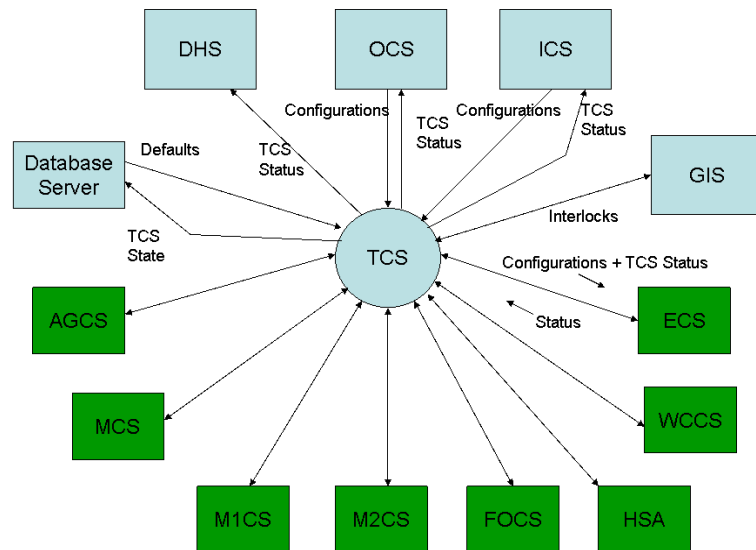


Figure II-5. Telescope control interfaces.

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.

1.1.4.7 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.

1.1.5 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 <http://atst.nso.edu/site/>. 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 Roque 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 developments and environmental permitting, enclosure design, and development of the support and operations buildings.

1.1.5.1 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 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.

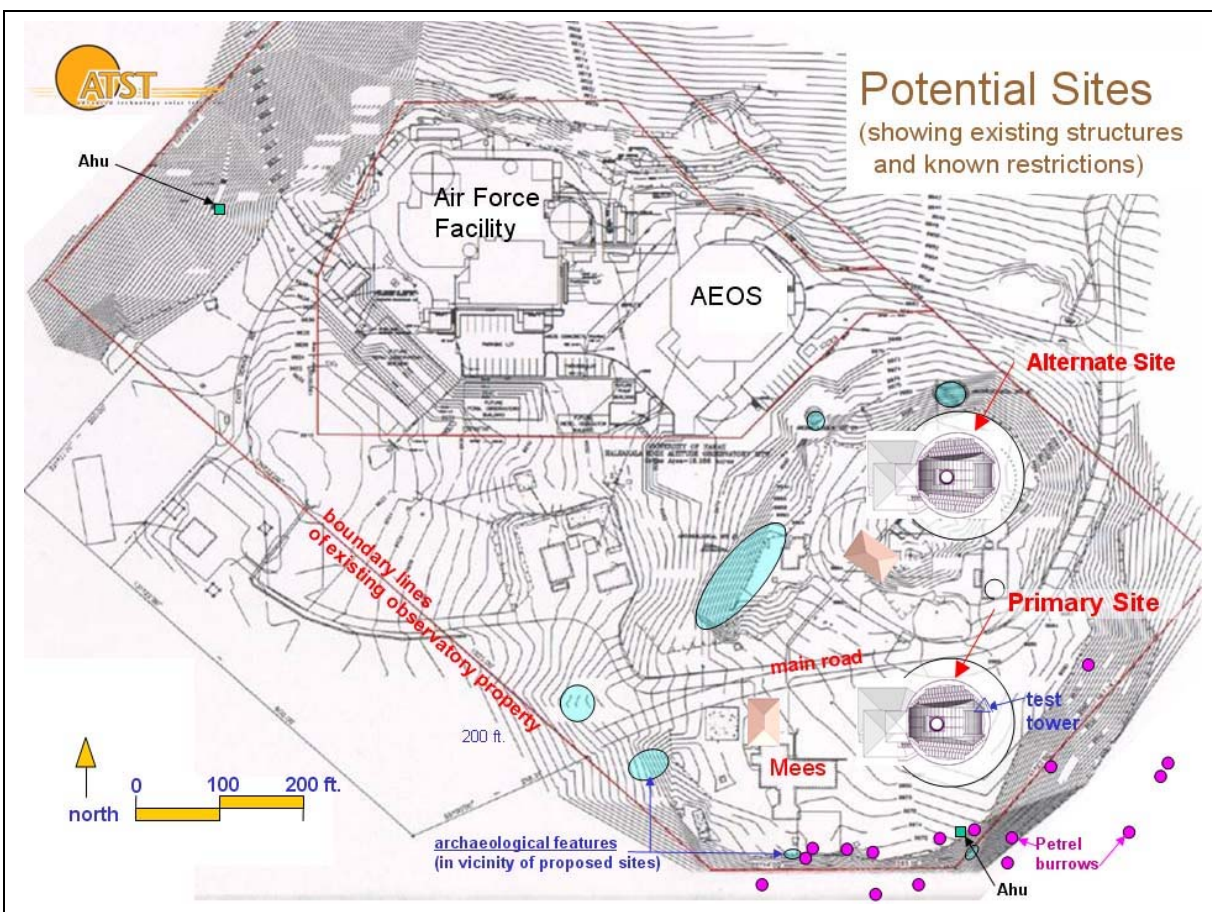


Figure II-6. An overview of the primary and alternate sites, including existing structures and known restrictions.

To support the public meetings, a final version of the entire ATST facility (e.g., exterior building envelope) was 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 II-7). 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.

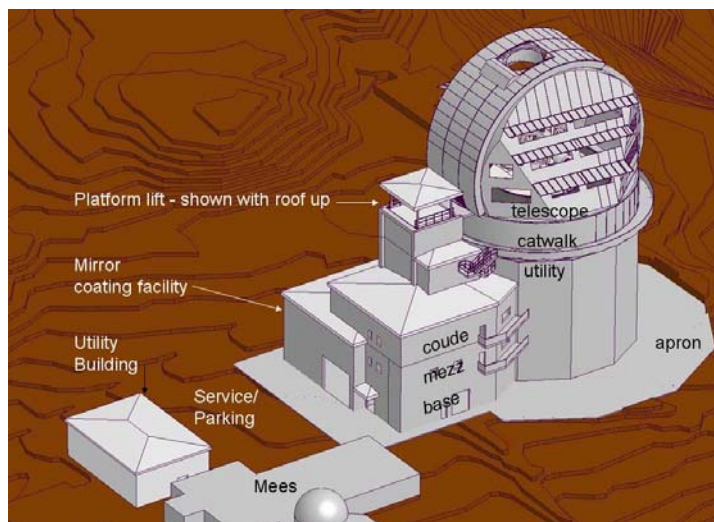


Figure II-7. An aerial view of ATST at the primary site. Note the proximity to the existing Mees solar facility.

1.1.5.2 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.

1.1.6 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.

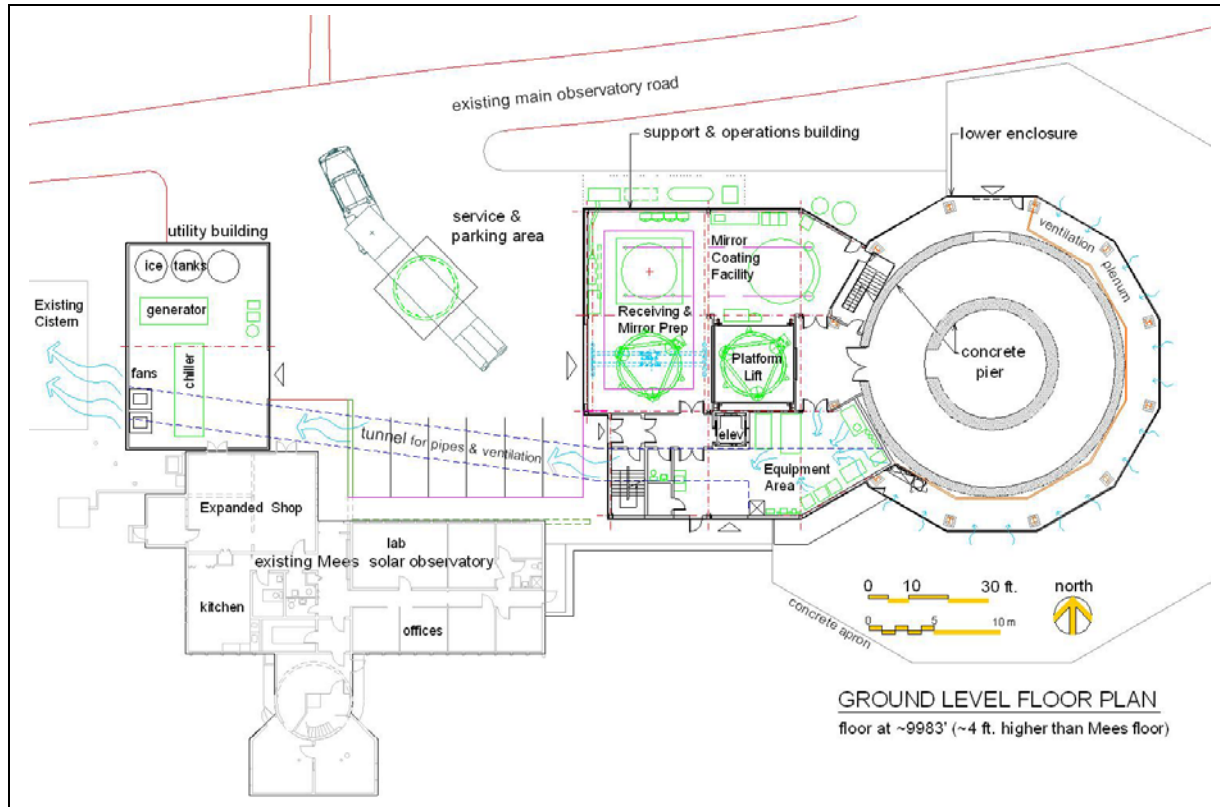


Figure II-8. A ground-level floor plan of the ATST facility. The support building as three main levels: ground, mezzanine, and coudé/control-room.

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.

1.1.7 Budget for Design and Development (D&D) Phase Completion

The provided D&D funding does not include funds to bring the designs to the final design level. We therefore anticipate completing the design effort after the beginning of MREFC funding. Our planning now takes into account a delay in the start of construction to FY 2008.

What has been described in this section is our planning associated with the current assumption that no funds to start major design completion contracts with industry will be made available in advance of construction

start. However, it is understood that delaying the final design contracts creates risk. Limited industrial involvement at this stage will require additional redesign by contractors at the start of construction. This will drive an increase in construction costs or force some de-scoping of capabilities and slow down the schedule as submitted in the construction phase proposal.

The planning now assumes that the NSF provides \$0.2M less in FY 2006 than planned, or funding of \$1.8M in FY 2006, and funding of \$2.2M in FY 2007 to support the design team and progress the designs towards construction funding. It also assumes that construction would begin in FY 2008. Table II-2 shows the effect of the \$0.2M reduction in D&D funding in FY 2006 and continued support of the EIS process.

TABLE II-2. ATST DESIGN & DEVELOPMENT FUNDING PLAN*(Dollars in Thousands)*

Fiscal Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	Total
ATST From NSF/AST	900	1,500	2,400	3,500	2,400	1,800	2,200			14,700
ATST From NSF/ATM	200	200		587	13	-	-			1,000
Yearly Funding Total	1,100	1,700	2,400	4,087	2,413	1,800	2,200	-	-	15,700
D&D Actual Expenditures										
D&D Actual Expenditures (payroll + non-Payroll)	79	1,656	2,415	2,450	2,641	1,196				10,436
D&D Remaining Expenditures										
Payroll						1,289	1,873			3,162
Non-Payroll (includes NOAO indirects, M&S, Travel, etc.)						350	639			989
Instrument Designs to PDR						150	-			150
Site A&E						150	-			150
EIS						100	-			100
Design Feasibility & Analysis Studies in High Risk Areas						530	200			730
Design Completion Contracts						-	-	3,875	3,975	
Running Balance	1,021	1,065	1,050	2,687	2,459	494	(18)	(3,893)	(7,868)	
Design Feasibility & Analysis Studies in High Risk Areas										
M1 Assembly Design Modeling (thermal, actuators)						100	100			200
Feed Optics Design Modeling (thermal, actuators)						50	-			50
Initial Optical System Alignment Procedure						50	-			50
AO DM Modeling (thermal)						100	-			100
Fast Tip/Tilt Modeling (thermal, control)						80	-			80
Wavefront Correction Control system Algorithm Development						50	-			50
Enclosure Design Modeling (thermal, control)						100	100			200
Running Balance						530	200	-	-	730
Design Completion Contracts to PDR/CDR Level with Industry (start as soon as funding is identified)										
Telescope Mount Assembly Design Completion to PDR/CDR								1,300	1,300	2,600
M1 Assembly Design Completion to PDR/CDR								1,300	1,300	2,600
M2 Assembly Design Completion to PDR/CDR								550	550	1,100
Feed Optics Design Completion to PDR/CDR								225	225	450
DHS Design Completion to PDR/CDR								-	100	100
Enclosure Design Completion to PDR/CDR								500	500	1,000
Running Balance								3,875	3,975	7,850

If construction funding is slipped beyond FY 2008, additional bridge funds will be required to support the design team in advance of construction. Table II-3 shows the effects of an FY 2009 start, assuming funding of \$3.0M is provided in FY 2008 to support the design team and progress the designs towards construction funding.

Due to the lack of funding for major design completion contracts with industry, we will not start any large vendor contracts but will increase in-house design efforts through additional hires. For example, a Controls Engineer has been recently added to the team. We will also pursue smaller targeted design feasibility and analysis studies with industry to support the in-house efforts to reduce risk. This will permit us to advance somewhat closer to final design, but carries risk in terms of redesign when construction contracts are eventually put in place. Design costs required to get to the same level of design completion will not be lower

with this in-house effort. Also, additional staff will increase personnel costs in the case of a further delay in the start of construction.

TABLE II-3. ATST DESIGN & DEVELOPMENT FUNDING PLAN
(Dollars in Thousands)

Fiscal Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total
ATST From NSF/AST	900	1,500	2,400	3,500	2,400	1,800	2,200	3,000			17,700
ATST From NSF/ATM	200	200		587	13	-	-				1,000
Yearly Funding Total	1,100	1,700	2,400	4,087	2,413	1,800	2,200	3,000		-	18,700
D&D Actual Expenditures											
D&D Actual Expenditures (payroll + non-Payroll)	79	1,656	2,415	2,450	2,641	1,196					10,436
D&D Remaining Expenditures											
Payroll						1,289	1,873	1,929			5,091
Non-Payroll (includes NOAO indirects, M&S, Travel, etc.)						350	639	658			1,647
Instrument Designs to PDR						150	-				150
Site A&E						150	-				150
EIS						100	-				100
Design Feasibility & Analysis Studies in High Risk Areas						530	200	395			1,125
Design Completion Contracts								-	3,875	3,975	
Running Balance	1,021	1,065	1,050	2,687	2,459	494	(18)	(0)	(3,875)	(3,975)	
Design Feasibility & Analysis Studies in High Risk Areas											
M1 Assembly Design Modeling (thermal, actuators)						100	100				200
Feed Optics Design Modeling (thermal, actuators)						50	-				50
Initial Optical System Alignment Procedure						50	-				50
AO DM Modeling (thermal)						100	-				100
Fast Tip/Tilt Modeling (thermal, control)						80	-				80
Wavefront Correction Control system Algorithm Development						50	-				50
Enclosure Design Modeling (thermal, control)						100	100				200
Running Balance						530	200	-	-	-	730
Design Completion Contracts to PDR/CDR Level with Industry (start as soon as funding is identified)											
Telescope Mount Assembly Design Completion to PDR/CDR								1,300	1,300		2,600
M1 Assembly Design Completion to PDR/CDR								1,300	1,300		2,600
M2 Assembly Design Completion to PDR/CDR								550	550		1,100
Feed Optics Design Completion to PDR/CDR								225	225		450
DHS Design Completion to PDR/CDR								-	100		100
Enclosure Design Completion to PDR/CDR								500	500		1,000
Running Balance								3,875	3,975		7,850

We will also continue to support the environmental impact studies for the Haleakalā site, which require additional petrel monitoring at an additional cost of approximately \$100K. *Note that the cost of the EIS process and the reduced D&D funding is severely limiting the number and scope of the risk mitigation studies that we can initiate and pursue with industry.*

The design feasibility and analysis studies are targeted toward identified risk areas (i.e., performance, cost, and schedule—critical path and near critical path items). The studies will allow the team to advance the designs further while supporting the refinement of the requirements, interfaces, and statements of work required for the later design completion contracts with industry. By conducting the studies now, we will place the project in a much stronger negotiating position with industry. We should, therefore, be able to reduce the overall design effort and rework with industry and thereby reduce the program's overall cost.

1.2 Adaptive Optics (AO)

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

The high-order AO development has been brought to a successful conclusion. The project, carried out in primary partnership with the New Jersey Institute of Technology, has resulted in two fully operational AO systems at the 76-cm Dunn Solar Telescope (DST) at Sacramento Peak. A similar system was deployed at the 65-cm telescope at Big Bear Solar Observatory (BBSO). The NSF has sponsored this project within the Major Research Instrumentation (MRI) program with substantial matching funds from the participating partner organizations, which include the NSO, the NJIT, the Kiepenheuer Institute in Germany, and the Air Force Research Laboratory.

The high-order AO systems have upgraded the DST to a diffraction-limited solar telescope, greatly increasing user demand and improving the DST's scientific output. The two identical AO systems are well matched to seeing conditions at the DST and feed two different instrument ports that can accommodate a variety of facility-class instrumentation, such as the Diffraction-Limited Spectro-Polarimeter (DLSP) and the new Spectro-Polarimeter for Infrared and Optical Regions (SPINOR). Experimental setups and visitor instruments, such as the Italian BI-dimensional Spectrometer (IBIS), can also be accommodated. This has made the DST the most powerful facility in terms of post-focus instrumentation.

The resulting systems also serve as proofs-of-concept for a scalable AO design for the much larger 4-meter ATST. Compared to the low-order AO system that has been operating at the DST since 1998, the high-order AO system provides a threefold increase in the number of deformable mirror actuators that are actively controlled. The DST systems will serve as test beds for the development of the ATST AO system. For example, we plan to test reconstruction algorithms needed for the ATST AO, where the pupil on the deformable mirror will rotate with respect to the wavefront sensor.

Another important aspect of this project is the development of AO data-reduction techniques and tools. The interpretation of AO data for an extended object like the Sun is challenging. The AO point spread function, and temporal and spatial variations thereof, must be understood in order to be able to interpret high-resolution imaging and spectroscopic data of solar fine structure. The performance limitations of solar AO systems also have to be understood. AO technology and AO data-reduction tools have been developed by a graduate student and in collaboration with the Center for Adaptive Optics (CfAO) and researchers at the Herzberg Institute in Canada. The work is expected to be completed in 2006.

With the completion and deployment of the high-order AO systems at the DST and at BBSO, the technical efforts of the AO project are now focused on the development of multi-conjugate adaptive optics. The Sun is an ideal object for the development of MCAO since solar structure provides the "multiple guide stars" needed to determine the wavefront information in different parts of the field of view. During FY 2004, the loop was successfully closed on the MCAO system for the first time and the extension of the corrected field by the MCAO system in comparison to MCAO was demonstrated. The NSO system is one of the first successful on-sky MCAO experiments (the Kiepenheuer MCAO system being the other). During FY 2005-FY 2006, additional MCAO work will focus on evaluating and improving the system performance and making comparisons with model predictions. The major challenge is to develop and implement efficient control algorithms and find optimum and practical positions for the deformable mirrors. More wavefront sensor subfields may also have to be added. The solar MCAO experience will be very valuable to the entire astronomical community. The NSO's main goal, however, is to develop MCAO technology for the ATST.

2 Instrumentation Program

2.1 Dunn Solar Telescope (DST)

The instrument program at the DST has its primary focus on exploiting diffraction-limited solar polarimetry, spectroscopy and imaging. The program is carried out in strong collaboration with both national and international groups, thus using NSF funded resources to leverage a much broader base of support. Major efforts to be completed within the next two-to-three years include commissioning the DSLP (with HAO) as a user instrument, bringing SPINOR on line (with HAO), fully integrating an imaging vector polarimetric capability with IBIS (with Arcetri Observatory in Florence) and installing an IR spectral polarimeter (with the University of Hawaii), and upgrading the DST control system to handle the advanced instrumentation. The upgrade task is to replace obsolete and unreliable telescope control hardware that can no longer be maintained. The upgrade will be limited to just those functions that are needed to operate the new instrumentation in the most advantageous manner.

2.1.1 Diffraction-Limited Spectro-Polarimeter (DLSP)

The Diffraction-Limited Spectro-Polarimeter is now fully integrated with one of the high-order AO systems (port 2). A 1Å K-line imaging device and a high-speed $2K \times 2K$ G-band imager with speckle reconstruction capability as well as a slit-jaw imager have been integrated with the DLSP and high-order AO as permanent capabilities. A diffraction-limited resolution mode (0."09/pixel, 60" FOV) and a medium-resolution mode (0."25/pixel, 180" FOV) are available. The Universal Birefringent Filter (UBF) can be combined with the DLSP/imaging system. The full-up instrumentation set is now available for users. An online data reduction tool will be available within the next year or two. As was the case for the DLSP development, this will be done in close collaboration with the High Altitude Observatory. The raw data from the DLSP will be calibrated and a Stokes inversion will be performed on the fly. There are plans to make the reduced data available via the Virtual Solar Observatory.

The DLSP will be used to implement a "solar queue observing mode" at the DST. Pre-defined observations, or observations of targets of opportunity, will be carried out by the observing support staff. Implementation of this mode will allow for more efficient use of the best seeing conditions. A similar operating model is envisioned for the ATST, and the DST/DLSP experience will be crucial for developing an efficient operations strategy for the ATST.

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

SPINOR is a joint HAO/NSO program to upgrade the existing Advanced Stokes Polarimeter (ASP) at the Dunn Solar Telescope. The ASP has been the premier solar research spectro-polarimeter for the last decade. Its ability to explore new spectral lines and to observe in multiple lines simultaneously is still unique. However, the ASP wavelength range is restricted to the visible, limiting its ability to sample new solar diagnostics, and its hardware is becoming outdated and difficult to maintain. HAO has received National Center for Atmospheric Research (NCAR) funding to start building SPINOR. SPINOR extends the wavelength of the ASP from 750 nm to 1600 nm with new cameras and polarization optics, provides improved signal-to-noise and field of view, and replaces obsolete computer equipment.

The first scientific test runs of SPINOR were conducted during 2005. While producing some exciting data, these runs also revealed some bugs which are currently being ironed out. For the test runs, an IR camera was borrowed from the HAO coronal one-shot experiment. This is an expensive and delicate camera system so HAO and NSO are currently working out an agreement to jointly purchase a dedicated IR camera system for SPINOR.

Software control of SPINOR will be brought into the DST control system as opposed to the stand-alone ASP and will therefore be phased with the DST control system upgrade. SPINOR will augment capabilities for research spectropolarimetry at the DST and extend the lifetime of state-of-the-art research spectropolarimetry at the DST for another decade.

2.1.3 Infrared Spectropolarimeter

This is a collaborative project between the National Solar Observatory and the University of Hawaii Institute for Astronomy (IfA) to provide a facility-class instrument for infrared spectropolarimetry at the Dunn Solar Telescope. H. Lin (IfA) is the principal investigator of this NSF/MRI funded project. This instrument will be able to take advantage of the diffraction-limited resolution provided by the AO system for a large fraction of the observing time at infrared wavelengths. Many of the solar magnetic phenomena occur at spatial scales close to or beyond the diffraction-limited resolution of the telescope. NSO has made tremendous progress in adaptive optics instrumentation to provide the highest quality images possible on its existing telescopes in the past few years, and as of now, both Ports 2 and 4 at the DST are equipped with high-order AO systems. The IR polarimeter will reside on Port 2. A dichroic beamsplitter will be used to direct infrared light to the instrument. The detector is a $1K \times 1K$ IR camera synced to a liquid crystal modulator. An engineering run was conducted in December 2005 and further runs are planned for 2006. The NSO is contributing mechanical design work and manufacturing, and will assist with electronic and software design.

2.2 McMath-Pierce Solar Telescope (McMP)

2.2.1 NSO Array Camera (NAC)

The NSO Array Camera (NAC) is currently running at the McMath/Pierce telescope and obtained first light in July 2005. The system can collect intensity spectra from the Main Spectrograph, and work is currently underway to implement a polarimeter system based on liquid crystal variable retarders so that polarization spectra can be obtained from 1000 nm to 2300 nm. The array has a low-read noise and practically no dark current during the typical solar exposure time. The $1K \times 1K$ images from the camera can be read and stored to disk at a rate of just over 10 frames per second. The NAC, which will use a $1K \times 1K$ InSb array to measure the solar spectrum from 1000 nm to 4660 nm, is the replacement for the NIM system and the NSO/CSUN IR camera system.

The NAC is one of only two $1K \times 1K$ IR cameras observing the Sun from 1000 to 4660 nm (currently the University of Hawaii has another similar device, and there are less than a handful of $1K$ arrays in the world that observe the Sun from 1000 to 2300 nm), so the NAC has enormous potential to collect unique and scientifically valuable solar observations. When coupled with the McMath/Pierce telescope (which provides the largest IR flux of any solar telescope), the NAC will produce new science results that will not be replicated at any other observatory.

The NAC instrument will target several exciting science questions using spectroscopy and polarimetry at infrared wavelengths. First, filament dynamics and magnetic field measurements using the He 1083 nm absorption line will be observed. The polarization of the He 1083 nm spectral line will provide critical tests of several magnetic models of filaments, and will be used to constrain modeling efforts currently underway at several institutes. The NAC instrument with its large format will be well-suited to study active region magnetic fields using the polarization of the Fe I 1565 nm spectral line. This line provides the most sensitive probe of the magnetic field in the quiet Sun and in parts of sunspots. Current tests using this line have been made with smaller cameras at the McMath-Pierce, and the instrumental contribution to the observed polarization is well-understood. The NAC instrument should make regular maps of the vector magnetic field of solar active regions for years to come. The plasma in the solar atmosphere will be studied in several ways with the NAC camera; the cold plasma of the chromosphere will be investigated using CO absorption lines at 4600 nm, and the hot plasma of the corona will be studied with emission lines from Fe XIII at 1075 nm and Si IX at 3934 nm. Finally, exploratory work at infrared wavelengths will be done using Ti I lines near 2200 nm, and using molecular lines throughout the wavelength range, in order to study sunspots and even to understand the basic physics of molecular line formation itself.

The NAC system is also planned to be a bridge to the ATST 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. Tests are planned with the NAC to make polarimetry observations beyond 2200 nm and the instrumentation developed during those tests will be directly applied to the ATST. Certainly the scientific discoveries, which will come from the NAC observing runs during the next few years, will drive near-infrared science programs at the ATST.

The established solar user community, which has produced science with the NIM instrument will be the community served by the NAC; and with its low-read noise and dark current, the NAC has the ability to make night-time observations at the McMath/Pierce in the IR.

2.2.2 McMath-Pierce Telescope Control System (TCS)

The McMath-Pierce telescope control system is scheduled for a comprehensive upgrade because the current hardware and software configuration present an unacceptable risk of catastrophic failure as well as a severely limited development environment. Key hardware components, such as the PDP-11/73 mini-computer and mechanical relays in the CAMAC chassis, are no longer available. The loss of a drive or relay leads to loss of telescope operation on the timescale of months. One of the goals of McMath instrument development like the NAC and Advanced Image Slicer (AIS) Integral Field Unit (IFU) is to fuel more sophisticated and efficient instrumentation design for ATST, but this development is difficult to accomplish in a software environment of disparate, decades old platforms.

The goal is to secure a vendor contract in FY 2006. We are in the process of defining a TCS specifications document that will be used to refine a preliminary request for quote (RFQ) created in fall 2005. The RFQ will be released by late spring 2006, followed by several months for vendor response and negotiation. The upgrade will take advantage of existing engineering experience within NSO, experience gained in the SOLIS project, as well as experience being gained with the commercial TCS of the upgraded East Auxiliary telescope. Detailed background information about the McMath-Pierce TCS upgrade can be found in Appendix E (2006 Facilities and Maintenance Plan).

2.2.3 Image Improvements at the McMath-Pierce

2.2.3.1 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 the 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 to be conducted in 2006 with full implementation on the main telescope as resources allow.

2.2.3.2 Adaptive Optics

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 2D 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 1D correction mode for solar limb observations.

Several improvements have been made to the system over the past year. The AO system is now capable of auto guiding 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 are available on the Web.

The predecessor to the full AO system is an image stabilizer based on the same high-speed piezoelectric tip-tilt 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.

2.2.4 Integral Field Unit for the McMath-Pierce

The Advanced Image Slicer (AIS) Integral Field Unit (IFU) will be the first instrument of its kind for a solar telescope. Its development and construction is a joint project of the New Jersey Institute of Technology and

the NSO, and supported by an NSF grant to NJIT (Deqing Ren, PI). The AIS IFU will enable simultaneous sampling of the AO-corrected field at the McMath-Pierce for 3-dimensional spectroscopy and polarimetry. The AIS IFU will take full advantage of the AO-corrected image, making the most efficient use of the telescope for spectroscopy and polarimetry at high spatial and high temporal resolution with high throughput. To address questions that cannot be studied at visible wavelengths, the image slicer IFU is optimized for the infrared (1.0–5.0 μm), although it can still work in the visible (0.36–1.0 μm) for multi-band wavelength diagnostics.

The IFU will be tested and used as a facility instrument at the McMath-Pierce Solar Telescope on Kitt Peak. The future 4-m aperture ATST will also require IFUs for its suite of instruments. Thus, this effort is the first step in developing IFUs for the ATST. The IFU instrument development is supporting one postdoctoral and one graduate student pursuing advanced instrumentation-based research programs. The AIS IFU will be completed in 2006.

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

1 NSO Telescope Operations

Through advancements in instrumentation and implementation of adaptive optics, NSO has maintained its telescopes at the cutting edge of solar physics. They play a key role in support of US and international solar research. The current NSO telescope upgrade and instrument development program is guided by the scientific and technical imperatives for a new ATST. Consequently, telescope and instrument upgrades and operations are reviewed and supported on the basis that they serve as necessary preludes to the ATST initiative while concurrently serving the needs of the scientific community.

1.1 Flagship Facilities

1.1.1 *Dunn Solar Telescope (DST)*

The 76-cm *Dunn Solar Telescope*, located on Sacramento Peak at an altitude of 2804 m, is the US premier facility for high-resolution solar physics. It is an evacuated tower telescope with a 76 cm entrance window. The evacuated light path eliminates internal telescope seeing. The image enhancement program over the past few years has included active control of the temperature of the entrance window to minimize image distortion and high-speed correlation trackers to remove image motion and jitter. The DST has two high-order adaptive optics systems feeding several optical benches. These systems provide diffraction-limited seeing under moderate to poor conditions making possible stunning time sequences of not only images, but of spectral sequences leading to vector magnetic field and Doppler measurements.

Past observations with the DST provided a picture of convective overshoot in the solar atmosphere, led to the realization that solar oscillations are global in nature, and provided the first detection of the locations where the p -modes are excited. Recent diffraction-limited observations with the DST are providing new insights into the fundamental nature of convective overshoot and solar magnetic fields and activity. Using AO developed by the NSO with the DST in conjunction with the Advanced Stokes Polarimeter, developed by the High Altitude Observatory, detailed, quantitative measurements of the vector magnetic field associated with sub-arcsecond magnetic flux tubes have been accomplished. Much of our knowledge about sunspots and the evolution of solar active regions is being challenged by the new high-resolution observations. Detailed

measurements of sunspot penumbra have revealed the mechanisms leading to the Evershed flow. High-resolution observations of surface flows have revealed twisting motions and magnetic helicity changes prior to activity events, which may provide a basis for solar activity prediction. Other highlights include the first measurements of prominence magnetic fields, maps of sub-arcsecond convective motions inside magnetic pores, oscillatory magnetoconvection, measurements of weak fields inside granules and observations of magnetic reconnection in the chromosphere.

NSO users and staff are vigorously pursuing the opportunity presented by high-resolution, diffraction-limited imaging at the DST. This work continues to help refine ATST science objectives and requirements, and ensures the growth of the expertise needed to fully exploit ATST capabilities. With the advent of AO, the DST has seen an increase in proposal pressure and the over subscription rate has nearly doubled. Major science themes that this work will address include:

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

To support this science, the DST houses the wealth of instruments (see Table III-1). In addition, new instruments are being developed in collaboration with partners (see Section II-2 on Instrumentation). A major effort to be completed within the next two-to-three years is the DST control system upgrade. The task is to replace obsolete and unreliable telescope control hardware that can no longer be maintained. The control system upgrade is also required to enable the implementation of new instrumentation, such as SPINOR into the DST. ATST controls concepts will be developed and tested in close collaboration with the ATST controls group.

1.1.2 McMath-Pierce Solar Telescope (McMP)

The McMath-Pierce Solar Telescope on Kitt Peak, at an altitude of 2096 m, is currently the largest unobstructed-aperture, all-reflective optical telescope in the world, with a primary mirror diameter of 1.52 m and a thermally controlled light path. Thus, it is uniquely capable of panchromatic, flux-limiting studies of the Sun. In particular, it is the only solar telescope in the world on which investigations in the relatively unexplored infrared domain beyond 2.5 microns are routinely accomplished. The large light-gathering power, the extended wavelength range from 300 nm in the near UV to 20 m in the far IR along with the well-behaved polarization characteristics of the telescope are unique and have led to the first direct measurements of kilogauss magnetic fields outside of sunspots and the discovery of cold structures in the solar chromosphere. The East and West Auxiliary telescopes are among the largest solar telescopes (both with 0.9-m diameter and 0.8-m clear aperture) and share the same all-reflective, unobstructed design of the main telescope. The McMath-Pierce facility is scheduled for observing for more hours than any other large NOAO telescope on Kitt Peak because it used both day and night.

The low-cost AO system for diffraction-limited imaging in the IR is now in operation. A large-format 1024×1024 ALADDIN array camera system, as described in pages 18 and 19, saw first light at the McMath-Pierce in July 2005 with shared-risk visitor runs occurring in early FY 2006. This advanced IR array camera will replace the existing 256×256 IR system.

Other instrumentation that is used at the McMath-Pierce includes:

- ZIMPOL I visible polarimeter
- 1-to-5-micron imager and polarimeter
- 0.3-to-12-m grating spectrograph
- 0.3-to-20-micron Fourier Transform Spectrometer (FTS)
- 6-to-15-micron imager (NASA)
- 12-micron vector polarimeter (NASA)
- 37-actuator adaptive optics system
- High-resolution stellar spectrograph
- Tip-tilt correction to 7th magnitude
- Visible imager for near-Earth object (NEO) tracking

In addition, a new advanced image slicer (IFU, or Integral Field Unit) is being developed in an NSF/ATI-funded collaboration between the New Jersey Institute of Technology and the NSO. The advanced image slicer will provide simultaneous 2-D spectroscopy of AO-corrected fields in the infrared within two years. The mechanical parts for the IFU will be fabricated during FY 2006. The IFU system will be assembled, aligned and tested at the NJIT optical laboratory. The IFU is scheduled for delivery to the NSO in June 2006, and the on-site testing at the McM-P in conjunction with the Main Spectrograph will begin.

Scientific Utilization of the McMath-Pierce

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

Scientific progress at the McMath-Pierce of the kind described above has exploited the unique features of the telescope. Many areas in solar physics require the uniquely large light gathering capability of the telescope, or use the infrared capability of the all-reflecting optics, or utilize both features. As these features of the McMP are likely to remain unique until ATST is operational, the telescope will continue to produce vigorous new work in forefront themes in infrared solar physics, including:

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

During FY 2006, we are anticipating the pursuit of observational research at the McMath-Pierce in the following specific topics:

- The Hanle effect and related novel magnetic-field diagnostics.
- The “Second Solar Spectrum” as seen in the linearly polarized spectrum near the solar limb.
- Solar magnetic field measurements in the far IR at 12 microns.
- Penumbral moving magnetic features.
- Molecular spectroscopy of Evershed outflow in sunspots.
- CO layer heights.
- Molecular layers over sunspot umbrae.

In addition to these frontier areas of solar physics, the NSO serves as a host for investigations in atmospheric sciences and laboratory spectroscopy. The Fourier Transform Spectrometer (FTS), located at the McMath-Pierce Solar Telescope Facility, is a unique national resource in wide demand by atmospheric physicists and chemists, as well as astronomers and solar physicists. Thus, the McMath-Pierce FTS is a multi-disciplinary facility that has also been designated as an official complementary site for the Network for the Detection of Stratospheric Change (NDSC). The Earth atmospheric measurements that are made with the FTS are included in the NDSC archive. These non-solar programs will be supported by recently approved grants from the NSF/Chemistry Division and the NASA Upper Atmospheric Research Program.

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

The SOLIS suite of instruments is embarked on a 25-year program of producing high-quality synoptic solar data. SOLIS is a program to make optical measurements of processes on the Sun, the study of which requires well-calibrated, sustained observations over a long time period. SOLIS is now housed inside the clamshell atop the KPVT tower, which is now re-named the Kitt Peak SOLIS Tower (KPST). The major SOLIS instrument, the Vector Spectromagnetograph (VSM), started observations in the summer of 2003 using interim cameras. It has replaced the daily magnetograms produced by the Kitt Peak Vacuum Telescope (KPVT) and the KPVT was decommissioned in September 2003. In addition to the VSM, the Integrated Sunlight Spectrometer (ISS) is located in its thermally controlled room within the KPST. The ISS is conducting initial science observations as of this writing. The Full-Disk Patrol camera, the last of the suite of SOLIS instruments, remains to be completed and installed at the KPST during FY 2006. Several SOLIS data products are now available via the Internet and are being used by the research community and for space weather forecasting.

Initial data from the VSM confirm the innovative concept of the instrument and set a new standard for full-disk measurements of the solar magnetic field at moderate spatial resolution. A major effort is now in progress to calibrate and reduce vector magnetograms that have been obtained regularly with the VSM. Among the issues being addressed are a slow degradation of the polarization modulator used to make the vector magnetograms (scheduled to be replaced in 2006) and a practical resolution of the intrinsic ambiguity in which way the magnetic field component in the plane of the sky points.

New data reduction efforts have emphasized the regular production of high-quality vector magnetograms. A pipeline was built that ingests observed spectra, resolves them into Stokes polarization form, and then fits the observed spectra with a two-component model of the magnetic and non-magnetic solar atmosphere. The resulting maps show high intrinsic quality of the data. Other data reduction pipelines for VSM and ISS data are either running or being developed.

The budget available for operating SOLIS is only about 60% of what was originally proposed. Furthermore, long-time partner support of the synoptic program by NASA and NOAA has diminished or ceased. As a result, for example, the VSM observing day has been constrained to about four hours per day (seven days per week) due to limited observing support that includes four part-time observers (three supported by NSO and one supported by NASA). Two recent (2005) NASA grants awarded from the Living With a Star (LWS) program (J. Harvey, PI) are now supporting an additional observer, with a concomitant expected increase in VSM observing hours, and a post-doctoral fellow to exploit the new full-disk vector magnetograms produced by the VSM.

Once all of the SOLIS instruments are completed and consistently produce high-quality data, NSO will propose to build two additional SOLIS units in response to the desired capability outlined in the NAS/NRC decadal survey, “Astronomy and Astrophysics in the New Millennium.” These will be placed at distant longitudes and operated in collaboration with foreign partners to form a SOLIS network capable of much more complete coverage of transient solar activity. This may be done in cooperation with a proposal to the US Air Force to modernize the SOON network to ISOON.

1.1.4 Global Oscillation Network Group (GONG)

The Global Oscillation Network Group (GONG) is an international, community-based program to conduct a detailed study of the internal structure and dynamics of the Sun using helioseismology. In order to exploit this technique, GONG developed a six-station network of automated and extremely sensitive and stable solar velocity imagers located around the Earth to obtain nearly continuous observations of the Sun's “five-minute” oscillations. GONG's network ensures that at least two sites can see the Sun at all times, effectively providing continuous observations of the solar surface velocities. This overlap minimizes data lost to bad weather or technical problems, and at the 90% coverage level the few remaining gaps can reliably be filled to produce an essentially continuous data set. GONG's 1024×1024 pixel cameras obtain velocity, intensity, and magnetic-field images of the Sun's surface every minute. Once a week the data are shipped to project headquarters, where the data from all six sites are calibrated and merged to obtain normal mode frequencies for studying the global internal structure. With GONG's increased spatial resolution, we are also able to carry out local helioseismology using velocity images of small tracked portions of the solar surface to study small-scale three-dimensional features below the Sun's surface.

In addition to the operation of the instruments and data acquisition network, GONG has developed a data reduction and analysis system to process the observations and facilitate the activities of the scientific community. Analysis of the low-order global p -modes continues 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) toward the equator. The GONG++ data processing pipeline system focuses on high-degree ($\ell \approx 1000$) global p -modes to probe closer to the solar surface and on local helioseismology methods—tracking and remapping ring diagrams, time distance, and holography—to probe the inhomogeneous and intermittent structure below the surface. GONG is now continuously calculating near-real-time “farside” maps of the back of the Sun using helioseismic holography. In addition, GONG provides photospheric line-of-sight magnetograms and intensity images in the 6768 Å Ni line.

GONG results to date have substantially advanced our knowledge of the Sun's structure and dynamics, testing fundamental theories of physics and astrophysics, and we are now measuring significant structural variation with the sunspot cycle, as well as on shorter time scales. NSO will operate GONG's network of

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

- *Global p-modes, including pushing to high spherical harmonic degree* ($\ell \approx 1000$), to increase the precision of the measurements of the global structure, and track its variation with the solar cycle, as well as supporting the study of high spherical harmonic degrees, which probe closer to the solar surface.
- *Local helioseismology*, to probe the inhomogeneous and intermittent structures below the surface (tracking and remapping for ring diagram, travel time, and acoustical holography analysis).
- *High-resolution, high-cadence magnetograms*. Continuous, high signal-to-noise ratio, high temporal-resolution magnetograms will be of broad interest for field extrapolation science and evolution studies, and extend the SOLIS data by providing a continuous temporal context.
- *Farside imaging*. Near real-time images of the farside of the Sun will help forecast active regions up to two weeks before they rotate into view, providing useful information to a broad range of users ranging from solar astronomers planning upcoming observing campaigns to space weather forecasting.

1.2 Synoptic Facilities

1.2.1 Evans Solar Facility (ESF)

Currently the US Air Force provides support for the ESF to continue their synoptic coronal emission line program. The NSO uses the Evans to observe the Sun as a star in the Ca II K-line. This synoptic program has operated for approximately three solar cycles. Once the SOLIS Integrated Sunlight Spectrometer is operating and six months of overlapping data have been obtained, this program will be closed. Other users are given access to the facility if they can provide their own support. Currently, the High Altitude Observatory would like to use the facility for some experiments in coronal magnetometry if they can reach an agreement with the Air Force on operations.

1.2.2 Hilltop Solar Facility

Currently, NSO only uses the Hilltop for live video H-alpha images to detect solar activity, and to select targets for the Dunn Solar Telescope. The Hilltop also houses a coelostat that feeds an optical bench currently used for testing narrow-band filter systems and other instruments. The High Altitude Observatory has modified the coronal one-shot and is using this instrument to measure coronal vector magnetic field measurements.

2 Digital Library and Virtual Solar Observatory (VSO)

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic data sets over the Internet to the research community. Since the inception of the Digital Library in May 1998, more than 3.7 million science data files have been distributed to about 8,000 unique computers. These figures exclude any NSO or NOAO staff members.

The advent of the Internet is the key enabler of alternate modes of observing and data delivery. The Internet enables direct interaction between astronomers at remote locations with the on-site observers, and allows

rapid data dissemination. Perhaps most importantly, the Internet leverages the scientific return on the investment in the facilities by providing access to data archives. These archives can produce new scientific results well after the original data sets are obtained.

NSO has continued to improve its server for Web pages and data archives. This server currently has 20 Terabytes of disk space, and will eventually be equipped with 24-30 Terabytes of on-line disc storage. This is sufficient to hold about seven years of SOLIS data as well as the current Digital Library. Currently, the Digital Library holds the entire set of daily solar images from the KPVT, FTS data, GONG data, a portion of the Sacramento Peak spectroheliograms, and the first SOLIS magnetograms.

In order to leverage further the substantial national investment in solar physics, NSO is participating in the development of a Virtual Solar Observatory, the European Grid of Solar Observations (EGSO), and the Collaborative Sun-Earth Connection (CoSEC). The VSO provides a unified gateway to distributed solar data archives with access through the WWW. The system is being accessed approximately 25 times per day since Version 1.0 was released in December 2004. The current version, 1.2, provides access to 112 major solar data sets along with a shopping cart mechanism for users to store their search results.

The overarching VSO goal is to facilitate correlative solar physics studies using disparate and distributed data sets. Necessary related objectives are to improve the state of data archiving in the solar physics community; to develop systems, both technical and managerial, to adaptively include existing data sets, thereby providing a simple and easy path for the addition of new sets; and eventually to provide analysis tools to facilitate data mining and content-based data searches. None of this will be possible without community support and participation. Thus, the solar physics community is actively involved in the planning and management of the VSO. For further information, see <http://vso.nso.edu/>.

Table III-1. Telescope and Instrument Combinations FY 2006

Key: DST = Dunn Solar Telescope ESF = Evans Solar Facility GONG = Global Oscillation Network Group
 HT = Hilltop Telescope KPST = Kitt Peak SOLIS Tower McMP = McMath-Pierce Solar Telescope

<i>Instrument</i>	<i>Telescope</i>	<i>Comments/Description</i>
NSO/Sacramento Peak – OPTICAL IMAGING & SPECTROSCOPY		
High-Order Adaptive Optics	DST	60 – 70-mode correction
Advanced Stokes Polarimeter (ASP)	DST	Photospheric/chromospheric vector polarimetry, visible, 0.375 arcsec/pixel
Diffraction-Limited Spectro-Polarimeter	DST	6302 Å polarimetry, 0.1 arcsec and 0.25 arcsec/pixel
Universal Birefringent Filter (UBF)	DST	Tunable narrow-band filter, $R \leq 40,000$, 4200 - 7000 Å
Horizontal Spectrograph	DST	$R \leq 500,000$, 300 nm - 2.5 μm
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies
Littrow Spectrograph	ESF	$R \leq 1,000,000$, 300 nm - 2.5 μm
Various CCD Cameras	DST	380 - 1083 nm; Formats: 256 × 256 to 2K × 2K
Correlation Tracker	DST	Tip/tilt correction
40-cm Coronagraph	ESF	300 nm – 2.5 μm
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å
Hα Video	HT	Hα full-disk
NSO/Sacramento Peak – IR IMAGING & SPECTROSCOPY		
Horizontal Spectrograph	DST	High-resolution 1 - 2.5 μm spectroscopy/polarimetry, $R \leq 300,000$
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 μm spectroscopy/polarimetry
NSO/Kitt Peak – IR IMAGING & SPECTROSCOPY		
SOLIS Vector Spectromagnetograph	KPST	Stokes I – 1083 nm Stokes I & V – 854.2 nm Stokes I, Q, U, V – 630.15 & 630.25 nm
Vertical Spectrograph	McMP	0.32 - 12 μm, $R \leq 10^6$
1-m FTS	McMP	2200 Å to 18 μm, $R \leq 600,000$
NSO Array Camera	McMP	1 - 5 μm, 1024 × 1024, imaging spectroscopy
CCD Cameras	McMP	380 - 1083 nm, up to 1024 × 1024 pixel
ZIMPOL I	McMP	450 – 1100 polarimetry, 10 Hz, 300 × 400
IR Adaptive Optics (Prototype)	McMP	2 – 12 μm, shared risk use with vertical spectrograph
Stellar Spectrograph	McMP	380 – 1083 nm, $R \leq 10^5$
Image Stabilizer (Prototype)	McMP	Solar, planetary or stellar use to 7 th magnitude for use with the vertical or stellar spectrograph
NSO/GONG – GLOBAL, SIX-SITE, HELIOSEISMOLOGY NETWORK		
Helioseismometer & Magnetograph	California, Hawaii, Australia, India, Spain, Chile	2.8-cm aperture; imaging Fourier tachometer of 676.8 nm Ni I line; 2.5 arcsec pixels; 1-min. cadence.

IV EDUCATION AND PUBLIC OUTREACH

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

NSO EPO goals are:

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

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

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

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

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

1 Educational Outreach

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

Research Fellows. Although funding has limited the number of NSO postdoctoral positions, NSO continues to host several each year through grants. Several postdoctoral fellows have participated in the adaptive optics program both at NSO and NJIT. GONG has one, sometimes two, fellowship positions supported by NASA grants. During FY 2006 we plan to fill one or two fellowship positions to exploit the new high-resolution capabilities and to participate in the ATST program.

Thesis Students. NSO annually hosts students working on advanced degrees. Typically, NSO staff members serve as adjunct faculty and act as the local thesis advisors. Thesis students during the past years have included Dave Byers (PhD, Utah State University), Jose Céja (MS, University of California, Northridge), Michael Eydenberg (MS, New Mexico Tech), Klaus Hartkorn (PhD, NJIT), and Jose Marino (PhD candidate, NJIT). Their work has included development of image reconstruction for AO systems, high-resolution observations of magnetic structures using adaptive optics, the development of an IR camera system, and the prediction of solar activity. Marino's work, in particular, has helped in defining the point spread function produced by the high-order AO system at the Dunn Solar Telescopes. Two new students, Andrew Medlin (MS candidate, New Mexico Tech, working on chromospheric Alfvén Waves) and Brian Harker-Lundberg (Utah State University PhD candidate working on modeling active region magnetic fields) began thesis work at the NSO in 2004.

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

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

guidance throughout the year. These teachers in turn form a cadre for developing classroom programs that can be disseminated to broader audiences.

Examples of modules that were developed for younger students include the Data and Activities for Solar Learning (DASL) and Research in Active Solar Longitudes (RASL), and the K-3 solar music educational module from GONG data. We will build on this experience to construct modules on solar magnetism, initially based on SOLIS data and then working in ATST goals.

Project ASTRO. Project ASTRO is an educational outreach program initiated by the Astronomical Society of the Pacific to build relationships between astronomers and educators by encouraging interaction in the development and execution of astronomy activities in the classroom. NSO provides guest astronomers for the program and hosts an annual workshop for astronomers and educators. To complement Project ASTRO and TLRBSE, NSO is developing a proposal for a solar system model for the Sunspot Astronomy and Visitor Center. The model ultimately will include an 18-ft diameter walk-through model of the Sun and scaled models of the planets at the Visitor Center, and planet markers along the Sunspot Scenic Byway (NM 6563) stretching to Cloudcroft and Alamogordo. (The markers are a means to draw visitors to our model of the Sun.) This scale also approximates the size of the Starlab planetarium domes used in some ASTRO and TLRBSE projects. NSO will develop class exercises for students to build models of sunspots and Earth to scale using the Starlab dome as the size of the Sun. Included will be exercises on the basic magnetic nature of the Sun.

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

New Programs. NSO would like to undertake three new EPO initiatives and include them as part of the EPO section of the ATST construction proposal. These initiatives include: *Magnetic Carpet Ride* (formerly Max 2008), *The Goldilocks Star* (formerly Other Suns for Other Worlds), and *The Sun on Wheels*. These will be designed to complement TLRBSE and Project ASTRO as well as outreach to schools and public programs. *Magnetic Carpet Ride* will take advantage of the anticipated Cycle 24 maximum that starts around 2007-2008, the centennial of Hale's discovery of solar magnetism (2008), and the International Heliophysical Year (IHY, 2007). It will develop classroom and temporary museum exhibit activities relating to the magnetic nature of the Sun and building on the "magnetic carpet" metaphor for the fine-scale structure of the solar magnetic field. *The Goldilocks Star* will take the natural interest in nighttime astronomy and the hunt for other planets supporting life as a means of teaching about our Sun. This will be a multidisciplinary project, with classroom and museum components, covering aspects of physics and life sciences. Portions of this activity will complement the Kepler Mission, which will search for earthlike planets. *The Sun on Wheels* will be a van equipped with telescopes, lesson plans, and other materials that can take *Magnetic Carpet Ride*, *The Goldilocks Star*, and existing programs to schools and public events. To help establish the need for these activities, the EPO officer will develop public questionnaires to determine the extent of public understanding about solar magnetism and about habitable stars. A preliminary inquiry at the Cloudcroft (NM) High School in early 2005 revealed that a number of students think solar magnetism holds the planets in orbit. Operating and staffing requirements for *The Sun on Wheels* will be defined in 2006. The telescopes initially will be ATST survey telescopes adapted for public programs. Advanced imaging systems will be added as the program

evolves. Funding will be sought through NSF and other organizations. NSO's EPO officer will represent the NSO in public affairs activities for the IHY and in an AAS/SPD public outreach committee now being formed.

2 Other Outreach

In late summer 2004, the NSO joined as a co-investigator with the University of Arizona in the submission of a proposal to a new NSF program entitled "Faculty Development in the Space Sciences." This novel program, administered by the NSF Atmospheric Sciences Division, 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 University of Arizona Department of Planetary Sciences, Lunar and Planetary Laboratory, invited the NSO to collaborate with them in the submission of a proposal for a new faculty position in solar physics. 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.

At the Sunspot Astronomy and Visitor Center, we have completed the live solar viewer that will project a white-light image of the Sun from a heliostat outside the Visitor Center to a screen inside the center. Components of Magnetic Carpet Ride will be developed for use in the Visitor Center. It will include a combination of computer stations with interactive graphics, hands-on units, and models of the Sun and of a sunspot. As a pathfinder for this exhibit, NSO will develop classroom activities to teach junior high and high school students about solar magnetism. This will include a combination of hands-on activities for students and demonstrations that would be conducted by teachers or an NSO officer. These activities will evolve into the educational activities and public information that would accompany a museum exhibit. Additional exhibit materials include new display panels for the Dunn Solar Telescope lobby and the Visitor Center to highlight current observing programs at Sunspot. We also are defining a computer kiosk that would provide access to real-time imagery from ISOON and allow visitors to perform simple image manipulations through a subset of IDL routines used by the ISOON team. Both the exhibit and kiosk will be designed to be transportable so they could be used at either the Sunspot or Kitt Peak visitor centers or by other members of the Southwestern Consortium of Observatories for Public Education (SCOPE).

NSO will investigate the potential for building an ATST Visitor Center at an appropriate location on Maui. We will meet with outreach counterparts from the Institute for Astronomy, Air Force, and other Haleakalā tenants, and local cultural and educational representatives, to define interest a joint visitor center (with shared overhead costs and floor space).

NSO will exhibit again at the National Science Teachers Association annual convention and will join the Association of Science and Technology Centers. NSO will join the outreach component of NASA's Living With a Star (LWS) program, a broad, powerful outlet for NSO materials and messages. NSO continues to participate in SCOPE, a consortium of research institutions in the southwest that promote a public awareness of astronomy through access and education.

3 Media and Public Information

Print Products. NSO has published a 20-page booklet describing the ATST and its science mission. Work has been started on a press kit on ATST (fact sheet, technical news reference, image collection), and fact sheets and trifold on SOLIS and GONG. NSO also produced a two-page fact sheet, "A Quick Tour of the

Sun,” for use at the visitor centers in Sunspot and at Kitt Peak. An online project book for ATST is being developed which supports development of the technical news reference and other media-related materials.

Web-Based Outreach. The Ask Mr. Sunspot feature will be revamped to streamline past answers into a comprehensive set and to write new tutorials about the Sun and ATST. Web stories anticipated in FY 2005 include SOLIS becoming operational, the AO/DLSP combination at the Dunn Solar Telescope, and expansion of ISOON capabilities. Other stories will be based on observing programs at Kitt Peak and Sunspot and of science papers published by the NSO staff. With the Scientific Visualization Studio at NASA's Goddard Space Flight Center, the NSO will explore new computer visualization concepts. NSO also is developing a streamlined online catalog of solar and instrumentation images for use by the public and the media.

V MANAGEMENT AND BUDGET

1 NSO Organization

NSO is organized to support operations of its flagship and synoptic facilities on Sacramento Peak and Kitt Peak, operate the global GONG network, and develop the ATST. Because of its size, many NSO staff support two or more functions. Examples include Keil, who serves as NSO director, ATST director/PI, and supervisor for the scientific staff at NSO/SP. Giampapa serves as NSO deputy director, SOLIS PI, Tucson site manager, and supervises the NSO/T scientific staff. Rimmele, serves at DST program scientist, leads the AO and other projects for the DST, and serves as ATST project scientist. Hill leads the GONG program and also leads the NSO VSO effort and Digital Library. Many of the technical staff support current telescope operations and projects and provide support to the ATST project.

Because of these multiple roles, an NSO organizational chart is fairly complex. The high-level organizational chart in Figure V-1 reflects the flow of funds from the director's office to the various programs. Detailed charts are shown in Appendix G. The GONG scientific staff reports to the GONG program scientist. The NSO/T scientific staff reports to the NSO deputy director, as does the GONG program scientist, and the NSO/SP science staff reports to the NSO director.

NSO conducts operations and projects with a combination of positions funded from its base NSF support, "soft money" positions funded from projects and grants, and positions funded by its collocated partner organizations. In addition, NSO shares support personnel (e.g., shops, facilities maintenance, computing, administration) with NOAO in Tucson and on Kitt Peak. NSO also cost shares some technical support with Apache Point Observatory at NSO/SP. Funds for the NOAO shared services are in the NSO budget and are shown in the NSO spending plan (Section V-2). Appendix C shows the staffing levels for all but the NOAO positions.

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

NSO/SP operates several telescopes on Sacramento Peak in New Mexico as well as office, computing, instrument development and housing facilities for visitors and the resident scientific and technical staff. Major projects at NSO/SP include development of adaptive optics, upgrade of the DST instrument interface and control systems, implementation of SPINOR jointly with the High Altitude Observatory, and work on the ATST design. In addition, NSO/SP conducts experiments and minor projects to improve near-IR cameras and spectroscopy, narrow-band imaging in the visible and IR, and vector polarimetry techniques that can take advantage of high-resolution facilities.

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

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

When NSO begins construction of the ATST, the management structure will evolve over the next few years. When the ATST is completed, NSO will completely reorganize and consolidate its resources.

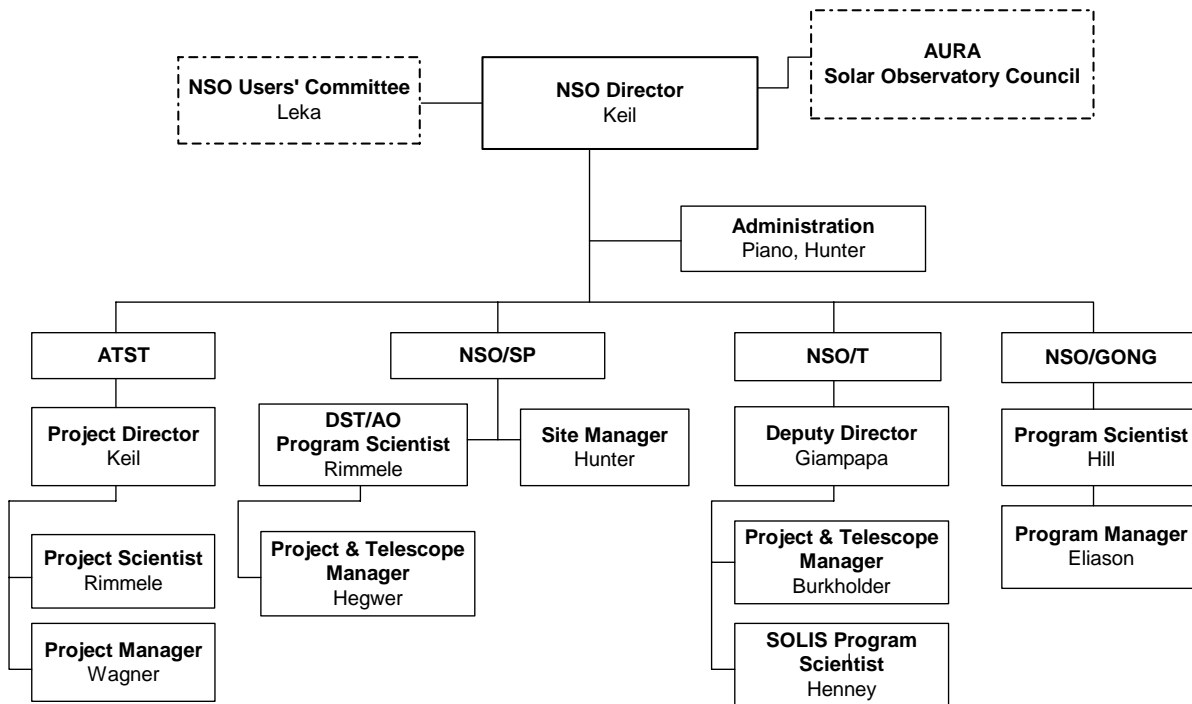


Figure V-1. NSO High-Level Organization Chart

2 FY 2006 Spending Plan

Table V-2 summarizes the NSO budget in FY 2006 for its current program of providing support to the US solar physics community and developing the ATST. The NSO program was developed based on receiving \$10,131K for its combined base program (Tables V-4 through V-9) and the ATST project (Table V-10). NSO also receives operational support from the Air Force Research Laboratory, under an MOU between the AF and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NSO earns revenue from operation of the cafeteria, the Visitor Center, and housing on Sacramento Peak. These funds are used to support the operations that generated them.

Table V-2. NSO FY 2006 Funding	
<i>(Dollars in Thousands)</i>	
NSF Astronomical Sciences Division Funding	\$10,131
NSF Atmospheric Sciences Division Funding	TBD
AFRL Support for Sac Peak Operations	400
NASA Support for Kitt Peak Operations	32
NSF REU/RET Program	116
Revenues (Housing, Kitchen, Visitor Center)	181
Total NSO Funding	\$10,860

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

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

**Table V-3. NSO FY 2006 Planned Spending
by Functional Area**

(Dollars in Thousands)

Director's Office ¹	368
AURA Corporate Fee	358
Educational & Public Outreach (EPO) ²	320
Tucson/Kitt Peak	1,580
Sacramento Peak	2,350
GONG	3,117
ATST D&D Effort	1,744
ATST In-House Contribution ³	701
SOLIS	321
Total NSO Program	\$10,860

¹Contains \$24K of programmed indirects.

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

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

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

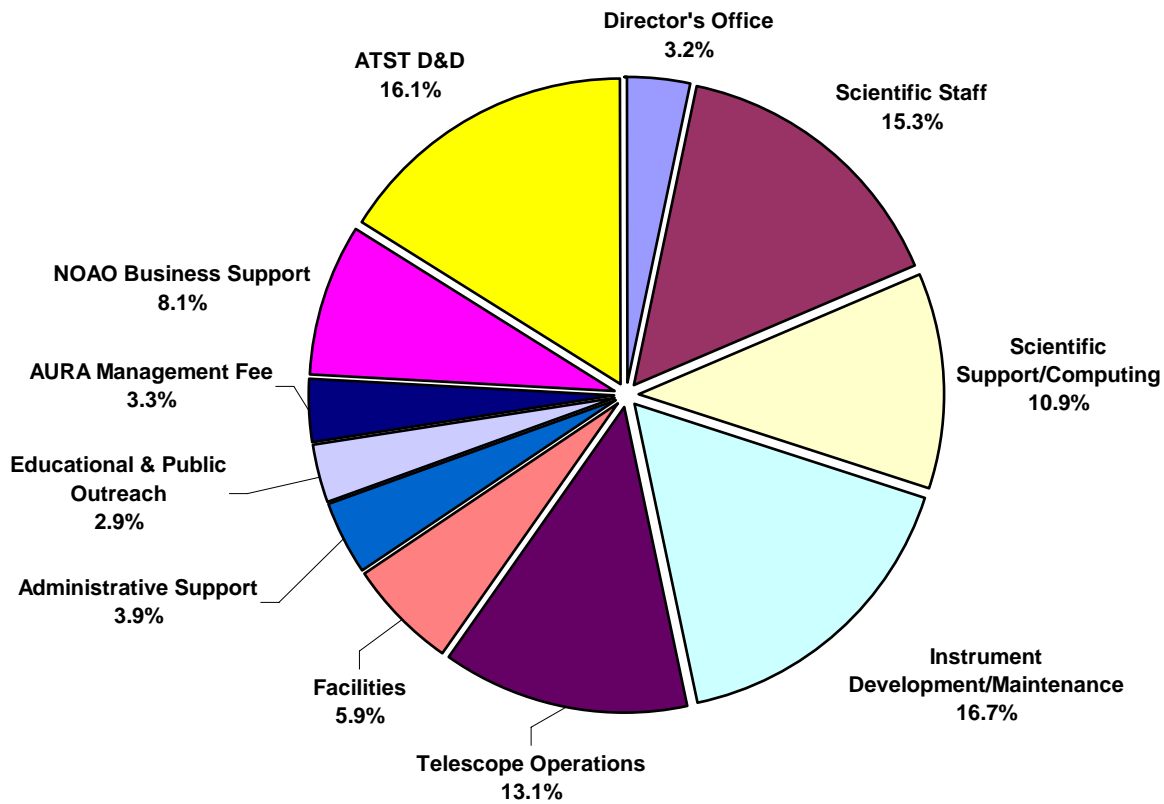


Figure V-2. *Distribution of FY 2006 Budget.*

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

Table V-4 presents the director's office budget. Some of the indirect amounts earned from non-NSF funded projects are budgeted towards operation of the director's office. Non-payroll expenses include travel, supplies and materials, and other miscellaneous expenses. Committees include the semi-annual meetings of the Users' Committee and support for other committee meetings as needed to support management of the observatory.

Table V-4. Director's Office			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Staff	314	25	339
Committees		12	12
NOAO Support	12	5	17
Total Director's Office	\$326	42	368
Outreach Support from NOAO	79	34	112

Table V-5 shows the budget breakdown for Tucson operations. Most of the instrument development program will be devoted to supporting the NSO Array Camera (NAC) and telescope control system (TCS) upgrade. The scientific staff salary line is considerably lower than shown last year because the salaries of those scientists who work primarily on GONG have been transferred to the GONG table (Table V-8). This was done to obtain a more accurate accounting for the GONG and Tucson programs. It should be noted, however, that the exact split between GONG, SOLIS, and the VSO varies, depending on evolving program needs. As SOLIS becomes fully functional and the demand for SOLIS data increases, we expect to adjust the funding.

Table V-5. NSO/Tucson			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	372	43	415
Scientific Support/Computing	189	10	199
Instrument Development	300	42	342
NOAO ETS & IRAF Support	105	0	105
Telescope Operations	144	76	220
NOAO Support	239	60	299
Total NSO/Tucson	1,349	231	1,580
Outreach (REU/RET)	46	12	58

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

Table V-6. NSO/Sacramento Peak			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	304	43	347
Scientific Support/Computing	167	114	281
Instrument Development	438	40	478
Telescope Operations	178	26	204
Facilities	288	351	639
Administrative Services	226	25	251
NOAO Support	119	30	149
Total NSO/Sacramento Peak	1,721	629	2350
Outreach (REU/RET)	105	45	150

Table V-6 contains the \$400K contribution of the USAF as well as the revenues earned from housing, meal services, and Visitor Center sales. The USAF funding is added to the general operations funding of the NSO to offset the support given to the Air Force Research Laboratory program at Sac Peak. This funding is down

\$50K from last year. Although the AF now has fewer people at Sunspot due to retirements, they plan to ramp back up. The additional costs will have to be recovered from overhead charges. Table V-7 provides an estimate of how these funds will be used to support the AFRL program. This varies from year to year based on program needs and facility usage.

Table V-7. Air Force FY 2006 Funding			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Support/Computing	55	29	84
Telescope Operations	35	18	53
Instrument Development	30	25	55
Facilities	64	66	130
Administrative Services	58	20	78
Total Air Force	242	158	400

Table V-8 summarizes the GONG spending plan for FY 2006. Although the table does not show an outreach line, the GONG scientific staff participates in the outreach program at Tucson and receives support from the NOAO outreach line shown in the director's office budget (Table VI-4). The science line now contains salaries of NSO/Tucson science staff that spend most of their time on GONG. This includes Frank Hill, John Leibacher and 50% of Jack Harvey. Additional personnel working on GONG are supported by grants from NASA (\$250K) and NATO (\$52K). These funds are not shown in the table.

Table V-8. NSO/GONG			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	715	35	750
DMAC Operations	513	170	683
Telescope Operations	542	549	1091
Administrative Services	161	16	177
NOAO Support	334	84	418
Total NSO/GONG	2,265	\$852	\$3,117

SOLIS spending is shown in Table V-9. SOLIS will also receive scientific support from within the NSO programs at Tucson and Sunspot. NOAO support is in the NSO/Tucson budget. Additional personnel funded under NASA grants support SOLIS operations. In FY 2006 these grants total \$199K and are not shown in the table.

Table V-9. NSO/SOLIS			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	84	0	84
Telescope Operations	87	150	237
Total NSO/SOLIS	171	150	321

2.1 ATST Program

Table V-10 summarizes the NSO in-house investment in the ATST. The full ATST spending plan, including the \$1,800K of new ATST projects and the funding brought forward from FY 2005 to FY 2006 is shown in Section II-1.1.7 (pages 13-15).

Table V-10. NSO IN-HOUSE CONTRIBUTION TO ATST			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Science Support	145	0	145
Technical Support	200	0	200
AO	236	80	316
IR	0	40	40
Total ATST In-House Contribution	581	120	701

The proposed design and development phase of the ATST project covered five years, beginning in the last few months of 2001 and ending in early 2006. The original plan was to transition from the D&D phase to a six-year construction phase that was planned for starting in FY 2006. Final designs at some of the vendors were planned for the early construction phase. Current guidance from NSF indicates that the project should plan for a 2008 or perhaps later start. To mitigate the risk associated with a later start of the construction phase, the ATST project is requesting additional D&D support in FY 2006 and FY 2007 to begin some of these final design efforts, as well as to complete environmental assessment of the recommended ATST site on Haleakalā. Section II-1.1.7 discusses these needs and Table II-2 (page 14) gives our estimates for costs.

Table II-2 assumes a “bridge funding level of \$1.8M in FY 2006 and \$2.2M in FY 2007. This funding level covers the efforts of the NSO design team, completion of the EIS, and support for a few industrial risk mitigation studies. The bottom section of the table shows the additional funding that is needed for final design efforts under the assumption that they are shifted into the construction phase once MREFC funds are acquired. Starting these efforts in 2006 and/or 2007 will substantially accelerate the project once construction commences and reduce overall project risk by ensuring the accuracy of the estimated construction costs. Thus we are requesting a program enhancement of approximately \$4M in each of FY 2006 and FY 2007 over and above planned bridge funding. If only smaller program enhancements are available, they would be targeted to the most critical (highest risk) design areas.

2.2 Funding Priorities

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

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

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

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

- Restructure base-funded project activities at NSO/SP to focus on technologies needed for the ATST. Concentrate on AO and telescope technology testing while aggressively seeking partners and funding for these activities. Delay, or indefinitely postpone, some non-critical maintenance items.
- Restructure base-funded activities at NSO/T not related to SOLIS development and operations in order to focus on ATST development. Concentrate on IR development and high-resolution imaging and spectroscopy in the infrared.

Both sites would contribute scientific staff time to ATST development (AO, IR technology, and design).

Activities at NSO that are supported by other agencies (NASA, AF, etc.) will continue as long as they are fully funded.

2. Operate SOLIS by devoting NSO resources formerly used to operate and reduce data from the KPVT. NASA plans to continue providing operational support and we continue to develop proposals to obtain additional support.
3. Operate the new high-resolution version of the GONG network.

2.3 Strategic Needs

The NSO long-range plan (FY 2005-2009) contains discussions of several areas where budget increases, beyond projected inflation increases, are needed to ensure effective support for the solar community with current NSO facilities. The budget increases would also position NSO for operating its new facilities, which will require increased levels of effort because of their complexity and greatly enhanced capabilities.

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

- An enhancement to the ATST D&D program of \$4M in FY 2006: This would provide funds to begin final design efforts at vendors for major subsystems of the ATST. This funding level represents an optimum scenario and is described in Section II-1.1.7 (pages 13-15) and Section V-2.1 (page 40). This level of funding will greatly reduce project risk, shorten the schedule and ensure a smooth transition into construction. Smaller enhancements will allow the project to start some of the needed vendor design efforts. These would be carefully chosen during the systems level review to maximize impact on both shortening of the schedule and overall cost.
- An enhancement of \$500K to the NSO base program: This would bring the NSO base program back closer to the amount in the recompetition proposal. It would provide \$120K for much needed postdoctoral support of ATST and SOLIS. \$130K would be used for telescope control upgrades at the Dunn Solar Telescope and McMath-Pierce Solar Telescope. Both systems currently use very outdated computers, with replacement parts hard to find and servicing becoming very difficult. The final \$250K would be used to strengthen the NSO support for SOLIS, Adaptive Optics, and data handling and analysis for the NSO Digital Library and Virtual Solar Observatory.

APPENDIX A: MILESTONES FY 2006

This section describes the major project milestones for 2006.

A1. Advanced Technology Solar Telescope

The most important goal for NSO is the construction of an Advanced Technology Solar Telescope, which will achieve high-resolution imaging (0.1 arcsec) in the optical on a regular and sustained basis. The ATST also will be capable of operating in the thermal infrared. Key activities include preparing the draft and final EIS documents. As well as continuing to prepare for design completion contracts and construction. Specific milestones for the ATST and related instrumentation programs include the following:

- Present the project to the National Science Board for inclusion in the MREFC funding line.
- Continue to develop funding partnerships for the construction phase.
- Support Haleakalā site EIS and CDUP process towards Record of Decision in October 2006.
- Complete follow-up activities associated with the recommendations from the October 2005 M1 Assembly Systems Design Review (SDR) and the scheduled January 2006 Telescope Mount Assembly, Enclosure, and Support Facilities and Buildings SDR.
- Prepare packages for and establish vendor design completion contracts as funds become available.

A2. Solar Adaptive Optics

- Conduct additional MCAO observing runs at the Dunn Solar Telescope.
- Conduct detailed MCAO performance evaluation.
- Complete the documentation for AO systems.
- Upgrade Port 4 AO optics to reduce chromatic aberration.

A3. Diffraction-Limited Spectro-Polarimeter

- Perform DST polarization matrix calibration.
- Develop and release data reduction software package.
- Develop near real-time data reduction process.
- Release the DLSP as a facility user instrument.

A4. SOLIS

- Complete modulator replacement for VSM instrument to improve Stokes parameter data quality.
- Replace VSM spectrograph grating retainers and instrument arm bushings to reduce flexure and improve grating position consistency for data acquisition.
- Assemble, test and install an extinction monitor to provide atmospheric line-of-sight conditions for ISS instrument.
- Complete assembly and alignment of FDP instrument, making it ready for integration to mount on SOLIS tower.
- Complete development of guider for VSM and FDP instruments.
- Provide a larger complement of observing programs and data products.
- Prepare initial science papers.
- Draft a plan for building a SOLIS network through partnerships.

A5. GONG

- Install the new magnetogram modulators around the network to reduce the zero point uncertainty to achieve the scientific objectives of coronal magnetic field extrapolations, and provide routine, near real-time magnetogram data products.
- Continue to develop local helioseismology methods, implement routine data production, and add new products to the archive.
- Enhance the farside processing and calibrate the farside signal.
- Replace the shelter at Learmonth.
- Complete the transition of production software from SUN Solaris to PC Linux.
- Secure increased bandwidth from the sites sufficient to transfer full-resolution images to Tucson in near real-time and complete the data handling system design.

A6. Virtual Solar Observatory

- Finish adopter's kit.
- Develop usage reporting tools.
- Provide spatial search capability.
- Develop graphical user interface (GUI).
- Provide IDL interface.
- Add more archives.

A7. NSO Array Camera (NAC)

- Complete near-IR (NIR) polarimeter.
- Conduct initial science observations of 4660 nm intensity spectroscopy.
- Conduct tests of mid-IR polarimeter components.
- Interface NAC and low-order AO.
- Achieve NAC electronic noise and spectrograph jitter reduction.
- Develop NAC storage area network (SAN).

A8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- Deploy Port 4 control computer, new polarization modulator motor/encoder, horizontal spectrograph (HSG) grating drive, HSG slit scan drive, prime focus slide drive.
- Upgrade Port 4 field-stop assembly.
- Modify ASP code to drive mechanisms via Port 4 control computer.
- Perform an NIR spectro-polarimetric survey of quiet Sun, active regions, and sunspots.
- Program and deploy SPINOR Experiment Control.
- Program Rockwell, PixelVision, and Sarnoff 'virtual cameras.'
- Complete universal camera mounts for new cameras.

A9. IR Polarimeter

- Assemble components and perform lab testing at the University of Hawaii, Institute for Astronomy.
- Conduct engineering runs at the DST.

A10. Dunn Solar Telescope Control and Critical Hardware (Systems Upgrade)

- Complete the requirements document for experiment control and critical hardware replacement.
- Develop baseline project plan.
- Establish control protocol and model definition.
- Develop command protocol with the Instrument Control Computer (ICC), Experiment Control Computer (ECC), and the CCD system.

A11. McMath-Pierce Telescope Control System (TCS) Upgrade

- Complete specifications document describing heliostat control system, including tie-ins with the spectrograph and instruments.
- Define scope of control system upgrade and translate specifications to systems requirements to be used for vendor bid.
- Hold peer review to refine system requirements.
- Translate system requirements to request for quote (RFQ).
- Release RFQ to control system vendors.
- Refine scope and requirements as needed in negotiation with vendors.
- Secure contract with vendor.

APPENDIX B: STATUS OF FY 2005 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2006 Program Plan. (FY 2005 milestones appear in italics below.)

B1. ATST

- *Integrate selected site into budgets, schedules and planning. Hold the Systems Design Review in March 2005.*
- *Present the project to the NSF Major Research Equipment Facilities Construction (MREFC) prescreening panel, then to the National Science Board for inclusion in the MREFC funding line.*
- *Establish vendor design completion contracts.*
- *Complete follow-up activities from the March Systems Design Review recommendations.*
- *Continue to develop funding partnerships for the construction phase.*

B2. Solar Adaptive Optics

- *Conduct additional MCAO observing runs at the Dunn Solar Telescope.*

Completed.

- *Conduct detailed performance evaluation.*

In progress.

B3. Diffraction-Limited Spectropolarimeter (DLSP)

- *Test and fine-tune the instrument and its associated software.*

Completed.

- *Integrate the DLSP camera with other instrument control computer (ICC) cameras.*

Completed.

- *Conduct a few scientific runs with the instrument.*

Completed.

- *Release the DLSP as a user instrument in 2005.*

The instrument is now available to users on a shared risk basis. Two important components must be completed before the DLSP is released as a facility user instrument. The components include performing a telescope polarization matrix calibration and developing data reduction software. The software is completed and ready to be released. The telescope calibration will be performed, weather permitting, during the next scheduled observing period.

B4. SOLIS

- *Start regular ISS observations. Complete and install an extinction monitor.*
- *Finish construction, testing, and installation of the FDP.*
- *Complete and install the guiders.*
- *Develop an upgrade path for the VSM cameras.*
- *Replace certain VSM optical and mechanical components.*
- *Provide a larger complement of data products.*
- *Develop a viable SOLIS operations plan with constrained funding.*
- *Draft a plan for building a SOLIS network through partnerships.*

All of the above are still in process.

B5. GONG

- *Design and build a new magnetogram modulator to reduce the zero point uncertainty to achieve the scientific objectives of coronal magnetic field extrapolations and provide routine, near real-time magnetogram data products.*

The project to upgrade the modulators and associated electronics is continuing. The new breadboard circuit reduced the zero point error by nearly an order of magnitude (from about 10 G to less than 0.3 G), and the new polarization modulators, which include a heater and require a thermal controller, have been characterized. Installation of the new modulators around the network should be accomplished by April 2006, making way for the routine production of quality magnetogram data products.

- *Start routine operation of the automatic image quality assessment software.*

Routine operation of the automatic image quality assessment software began with GONG Month 100.

- *Continue to develop local helioseismology methods, implement routine data production, and add new products to the archive.*

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 produced. Travel-time measurements (time-distance helioseismology) of 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 FY06. Two new data products have been added to the suite of “official” GONG products: merged velocity images and ring diagram parameters.

- *Start routine operation of the near real-time “farside” imaging pipeline.*

GONG is continuously computing farside maps of the Sun using helioseismic holography. Each map uses a 24-hour period of near real-time images sent to Tucson from the six worldwide network stations and the maps are displayed every twelve hours on our website.

- *Implement high spherical harmonic degree global p-mode processing.*

Due to the attrition of key data processing personnel, the priority of developing a high spherical harmonic degree global p-mode processing capability has been temporarily reduced.

- *Develop a plan for a complete replacement shelter and instrument.*

Two shipping containers were purchased and transformed into shelters for the GONG instrument. One will be sent to Learmonth, to replace the unit that is disintegrating due to its location near the sea: Additional measures to retard this process have been incorporated in the replacement. The swap is scheduled for May 2006; this time frame minimizes the impact on the overall performance of the network.

The second shelter will be filled with a new instrument that will reside at the Tucson farm as our hot spare station, providing insurance against catastrophic loss of a site and reducing the down time from 2-3 years to about 6 months. Procurement of available components is nearly complete, and fabrication of mechanical parts and production of custom electronics has started. Production and system integration should be completed in FY07.

- *Develop a plan to secure increased bandwidth from the sites sufficient to transfer GONG data near real-time.*

Most sites will require bandwidth upgrades to support the transfer of GONG data to Tucson in near real-time. Communications vendors have been contacted at each site location, needed hardware installations have been identified, and the cost has been estimated. Design of the data handling system will be completed in FY06.

- *Implement a 3-year software plan for GONG's data processing and development.*

Due to issues related to the transferring production code from the SUN Solaris operating system to the PC/Linux platform, the software plan has not been completed.

B6. Virtual Solar Observatory

- *Release V1.0 to the community.*

V1.0 released at Dec 2004 AGU meeting, current revision is at V1.2.

- *Release shopping cart utility.*

Released at AGU/SPD meeting, May 2005.

- *Release movie tool.*

Released at AGU/SPD meeting, May 2005.

- *Release adopter's kit.*

Needs to be improved.

- *Add more archives.*

Added TRACE, San Fernando Observatory.

B7. NSO Array Camera (NAC)

- *Integrate and test the controller and dewar with the NSO ALADDIN array.*

This has been completed; first light observations were taken in early 2005 in Hilo.

- *Conduct initial science observations at the McMath-Pierce; spectroscopy.*

This has been completed; first spectra at 1083, 1565, 2312 and 4660nm have been made. Initial science runs including observations at 1083nm of an X2 class flare were completed in the Fall of 2005.

- *Develop polarimeter interface software and observing scripts.*

Progress has been made on this, but the task remains incomplete. The polarimeter hardware is in-hand at NSO will be used too). A new LCVR controller is currently being tested in a lab set-up in Tucson. It is expected that the near-IR polarimeter will be functioning by the middle of 2006, with first science results in late 2006.

B8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- *Integrate achromatic optics (modulator, retarder) and integrate enhanced anti-reflection (AR) coated transfer optics.*

Completed.

- *Demonstrate half wave retarder at the polarizing beamsplitter, reduced fringe modulator, and Sarnoff cameras.*

Completed.

- *Define communication protocols for mechanism control and for virtual cameras.*

The virtual camera protocol is completed and has been sent to HAO. Mechanism control protocol is in progress.

B9. IR Polarimeter

- *Initiate system design and development with purchase of IR cameras, dewars, filter wheel assemblies, computers, and optics for the spectrograph.*

Still in process.

B9. Dunn Solar Telescope Control and Critical Hardware (System Upgrade)

- *Complete the requirements document.*
- *Establish control protocol and model definition.*
- *Develop command protocol with the Instrument Control Computer (ICC), Experiment Control Computer (ECC), and the CCD system.*

All of the above are still in process.

APPENDIX C: NSO FY 2006 BUDGET & STAFFING SUMMARY

NSO FY 2006 Budget Summary

	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total Budget
Director's Office	351,443						351,443
Scientific Staff		346,977	414,671	749,812	145,000		1,656,460
Science Support/Computing		281,162	199,287	682,792		84,054	1,247,295
Instrument Development/Maintenance		478,758	447,280	-	556,000		1,482,038
Telescope Operations		204,466	220,185	1,090,743		237,004	1,752,397
Facilities		639,068					639,068
Administrative Support		250,652		176,172			426,825
Educational & Public Outreach	112,435	149,637	58,000				320,072
ATST Site Testing					-		-
NOAO Business Support	16,915	149,250	298,500	417,900			882,565
ATST D&D					1,765,800		1,765,800
AURA Management Fee	302,209				34,200		336,409
Program Total	783,002	2,499,970	1,637,924	3,117,419	2,501,000	321,058	10,860,372
Revenue							
NSF ATST D&D from ATM Division					0		0
Programmed Indirects	(23,652)						(23,652)
Housing Revenue		(91,000)					(91,000)
Meal Revenue		(16,720)					(16,720)
NSF REU/RET Funding		(58,000)	(58,000)				(116,000)
Air Force Support		(400,000)					(400,000)
NASA Support			(32,000)				(32,000)
Visitor Center Revenue		(50,000)					(50,000)
NSF Astronomy Funding	759,350	1,884,250	1,547,924	3,117,419	2,501,000	321,058	10,131,000

FY 2006 Staffing Schedule

(In Full-Time Equivalents)

	Director's Office	Sunspot	Tucson	ATST	GONG	SOLIS	Total
Scientists	1.00	4.00	3.50	2.00	6.00	1.00	17.50
Engineering/Science Staff	-	7.00	6.00	9.00	7.00	-	29.00
Administrative Staff	1.00	4.50		3.00	2.00	-	10.50
Technical Staff	-	8.50	3.00	2.00	9.00	0.50	23.00
Maintenance & Service Staff	-	9.00			-	-	9.00
Total Base Program	2.00	33.00	12.50	16.00	24.00	1.50	89.00
AF Supported Science Staff	-	3.00	-	-	-	-	3.00
AF Supported Technical Staff	-	1.00	-	-	-	-	1.00
Other NSF Projects (AO, FTS/CHEM)	-	0.50	0.80	-	-	-	1.30
NJIT Postdocs, Graduate Students	-	1.00	-	-	-	-	1.00
NASA Supported Science Staff	-	-	4.75	-	3.70	-	8.45
NASA Support Engineering Staff	-	-	1.00	-	-	-	1.00
NASA Supported Technical Staff	-	-	0.80	-	-	-	0.80
Emeritus Science Staff	-	0.50	1.50	-	-	-	2.00
Visiting Scientists	-	-	1.00	-	-	-	1.00
Total Other Support	0.00	6.00	9.85	0.00	3.70	0.00	19.55
Total Working at NSO	2.00	39.00	22.35	16.00	27.70	1.50	108.55

APPENDIX D: SCIENTIFIC STAFF RESEARCH AND SERVICE

Karatholuvu R. Balasubramaniam, Associate Astronomer

Areas of Interest

Solar Magnetic Fields and Activity Evolution, Eruptive Solar Activity, High-Angular Resolution Solar Physics, Stokes Polarimetry, Advanced Technology Solar Telescope Instrumentation and Technology, Space Weather, Education and Public Outreach.

Future Research Plans

K. S. Balasubramaniam (Bala) will focus on understanding and modeling of physical processes in the solar atmosphere, including understanding the physics of solar activity and its influence on space weather. He will acquire and analyze high-angular, spectral and temporal resolution data from the Dunn Solar Telescope (DST) using adaptive optics and focal plane instruments including the Advanced Stokes Polarimeter (ASP), Italian Bidimensional Spectrometer (IBIS) tunable narrow-band filters, and spectrographs for this purpose. Bala will also use complementary full-disk from full-disk ground and space instruments to understand some of these phenomena. He will continue to play a leading role in defining the Tunable Imaging Spectroscopic Filter system for the ATST.

Research Thrust Areas and Recent Research Results

1. Inversion of Stokes spectral line profiles using principal component analysis (PCA) and genetic algorithms (GA).
 - In collaboration with his graduate student Brian Lundberg (Utah State), Bala plans to exploit an understanding of the applicability of PCA and GA to extract physical conditions in the solar atmosphere, an extension of the previous work on PCA.
 - In the near future, Bala, in collaboration with H. Socas-Navarro (HAO), plans to extend the results of PCA application to photospheric and chromospheric profiles, using a combination of neural network modeling and PCA, to infer magnetic fields.
2. Sunspots.
 - Filaments, Twisted Flux Tubes and Magnetic Reconnection about Sunspots.
 - In a comprehensive study, Bala uses a series of high-resolution spectroscopic and spectropolarimetric measurements to understand the structure of twisted flux tubes at the periphery of a sunspot, seeking evidence for reconnection. The diagnostic tools used for this purpose include magnetic and velocity fields at the photosphere and lower chromosphere (H α), and velocities in the upper chromosphere (Ca II K line). Finally, using extrapolation models, Bala deduces the structure of magnetic fields, their relationship to the formation of the filament structure, and magnetic channels.
 - Using high-resolution imaging spectroscopy measurements with the Universal Birefringent, Bala and S. Keil plan to seek signatures of rapidly moving magnetic elements that lead to reconnection at both the photospheric and chromospheric levels. The NSO high-order AO is aptly suited for this purpose.
 - Temporal Variations in the Evershed Flow and Sunspot Oscillations.
 - Working with A. Pevtsov, Bala is seeking to measure the sustenance and changes in the Evershed flow across sunspots using high-resolution spectroscopic data acquired with the DST. Doppler shifts were calculated from a unique, high-resolution dataset of 39 spectral lines, spanning the photosphere and chromosphere. The results indicate a quasi-periodic structure of the Evershed flow with a typical period between 18-24 minutes in the photosphere and 12-18 minutes in the chromosphere. Bala and Pevtsov discuss the implications of these results for both the siphon flow and the moving flux tube models. With additional computations and modeling, these results will be prepared for publication.

3. ATST. (a) Imaging Narrow-Band Filter. Working with G. A. Gary (NASA/MSFC) and B. Robinson (Univ. of Alabama, Huntsville, and former ATST Fellow), Bala has developed the design and ray tracing of the telecentric configuration of the triple-Etalon filter. The details of this design have been passed on to colleagues at the Kiepenheuer Institute, who are now the lead partners for the development of the ATST tunable filters.
4. In collaboration with H. Uitenbroek, Bala made some promising initial measurements of polarimetry due to molecular lines in the G-Band, as predicted by radiative transfer models. Additional measurements will be made, in an attempt to make reliable and sustained measurements in the G-Band and the Ca II K-line.
5. In collaboration with D. Neidig and A. Pevtsov and researchers elsewhere, Bala is attempting to understand the factors leading to large-scale, low-intensity chromospheric eruptions that are accompanied by filament eruptions, distantly connected flares, as well as mass ejections.

Service

Bala is a member of the NSO/Sac Peak (NSO/SP) Telescope Allocation Committee and advises non-NSO users on observing at NSO/SP facilities. He takes supportive responsibility for the NSF-sponsored REU/RET and SRA programs at NSO/SP and chairs these programs for NSO. Bala continues to be active with public outreach efforts, presenting public lectures, conducting tours, and participating in local school outreach. He serves as an NSO instrumentation lead in developing the dual Fabry-Perot system, and participates in the planning requirements for the ATST. Bala makes regular contributions to community processes such as proposal evaluations at NSF and NASA, and serves as a referee for papers submitted to the *Astrophysical Journal*, *Astronomy and Astrophysics*, and *Bulletin of the Astronomical Society of India*. He also helps in chairing scientific sessions at meetings. Bala is the research advisor for a PhD student from Utah State University. He serves on the US Planning and Organization Committee for the International Heliophysical Year (IHY) 2007 and is editor of the *IHY Newsletter*.

Olga Burtseva, Research Associate

Areas of Interest

Time-Distance Analysis, Global Helioseismology: Leakage Matrix

Recent Research Results

Future Research Plans

Burtseva intends to continue working on the above areas.

Michael Dulick, Scientist

Areas of Interest

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

Future Research Plans

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

Service

Dulick serves as the NSO FTS instrument scientist for visiting investigators funded under a grant from the NASA Upper Atmosphere Program and an NSF Chemistry grant for Laboratory Fourier Transform Spectroscopy, with specific duties that include providing assistance in the experimental design and setup and the instructional use of the instrument.

Mark S. Giampapa, AstronomerAreas of Interest

Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

Recent Research Results

Giampapa and his collaborators completed a draft manuscript for submission to *The Astrophysical Journal* on the results of a survey of chromospheric Ca II H and K line emission, and its variability during 1997-2001, in solar counterparts in the solar-age and solar-metallicity open cluster M67. The manuscript will be submitted in the second quarter of FY 2006. The survey was conducted using the WIYN telescope with the Hydra multi-object spectrograph on Kitt Peak. The results indicate the range of potential amplitudes of the solar cycle through observations of about ~100 solar-type stars that are presumably at random phases in their activity cycles. This is critical to know in view of the impact of solar variations on long-term global climate changes. One surprising result of this work was the discovery of solar-type stars that are noticeably more active than the Sun as seen at solar maximum. This may indicate that the potential excursion in the solar cycle is greater than seen so far in contemporary measurements or that these particular M67 stars are rotating more rapidly, which would be unusual for a cluster of this age.

Future Research Plans

Giampapa intends to continue working on the M67 project but now within the context of the joint University of Arizona/NOAO NASA Astrobiology program. Giampapa is a Co-Investigator in this program where his efforts focus on delineating the nature and evolution of the variable activity of solar-type stars that may be the hosts of extrasolar planetary systems. Specifically, Giampapa and his collaborators, including postdoc William Sherry, will examine the joint variation of irradiance and chromospheric (magnetic) activity in Sun-like stars in clusters ranging in age from ~100 Myr (e.g., the Pleiades) to solar age (e.g., M67 and possibly older clusters) in order to characterize the ambient radiative and deduced particle environments within which the evolution of planetary atmospheres occurs. In addition, a spectroscopic survey of Ca II H and K line activity will be carried out for the intermediate-age cluster, NGC 752. Further spectroscopic work on the M67 Sun-like stars, utilizing large aperture telescopes and high-dispersion spectrographs, is pending proposal review and approval.

Service

M. Giampapa is the deputy director for the National Solar Observatory. In this role, Giampapa assists the NSO director in the development of program plans and budgets, including budgetary decisions and their implementation, and the preparation of Observatory reports and responses to NSF and AURA requests. Giampapa currently serves as chair of the NSO Scientific Personnel Committee, which advises the director on personnel actions involving the scientific staff, including hiring and promotion. He also carries out on behalf of the NSO director supervisory responsibilities for the NSO Tucson/Kitt Peak program. In this role, he has overview responsibilities for the scientific and instrument development activities at NSO/Kitt Peak, including the SOLIS project, and the conduct and support for observing programs at the NSO McMath-Pierce Solar Telescope Facility on Kitt Peak. Giampapa is the PI for SOLIS as well as the instrument scientist for the SOLIS Integrated Sunlight Spectrometer (ISS); chair of the Kitt Peak Telescope Allocation Committee (TAC); chairman of the Tucson site Project Review Committee (PRC) and serves as a member of the full

NSO PRC; and, program scientist for the McMath-Pierce nighttime program. Giampapa represents the NSO on the NOAO Management Committee. He also serves as an editorial board member for *New Astronomy Reviews*. Like other NSO scientific staff members, Giampapa participates in educational outreach activities, including K-12, undergraduate, graduate, and general public educational programs and activities. Giampapa is an adjunct astronomer at the University of Arizona.

Irene González Hernández, Assistant Scientist

Areas of Interest

Local Helioseismology, Helioseismic Holography and Ring Diagrams

Recent Research Results

González Hernández started working on the GONG Farside (holography) project last November. This project is aimed at using GONG data in the context of space weather forecasting. She has been working with both the data used by the method (GONG near-real-time compressed velocity images) and the method itself. As a result, continuous farside maps are currently being calculated and displayed at the GONG Website, <http://gong.nso.edu/data/farside/>. González Hernández has also analyzed two years of GONG continuous data using a large-aperture 'ring diagram' technique to search for solar meridional circulation variability. The results show a marked correlation between the B0 solar angle and the presence of a circulation counter cell. A slight increase of the meridional circulation with depth is also found during the studied period. The paper will be published in the *Astrophysical Journal* in February 2006. González Hernández has dedicated part of her time to enhancing and supporting the 'ring diagram' pipeline for the GONG project. The pipeline is currently producing continuous synoptic flow maps of the solar subsurface up to a depth of 0.98R. As new results are analyzed, both the data calibration and the pipeline tools are improved to optimize the scientific findings.

Future Research Plans

González Hernández will work toward extending the farside maps to the full hemisphere and integrating the GONG magnetograms in the daily maps. She will also start the signal calibration by comparing the phase differences obtained by holography of the front side with the observed magnetic field. She will also continue to devote part of her time to supporting the Ring Diagrams pipeline as required.

Service

González Hernández is involved in Project ASTRO as an astronomer partner. She participated in the astronomical activities with 2nd grade students at Van Buskirk Elementary School in Tucson.

John W. Harvey, Astronomer

Areas of Interest

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results

During FY 2005, J. Harvey concentrated on SOLIS instrument and software development, on a NASA-funded effort to correct known errors in the archive of Vacuum Telescope data, and on optical modifications of the GONG instruments, leaving little time for research. Harvey used SOLIS chromospheric magnetograms to show that the dark 'circumfacule' phenomenon seen surrounding active regions in calcium absorption line observations is caused by diffuse material similar in spectral characteristics to large filaments. These diffuse fibrils are markers of a part of the solar atmosphere dominated by horizontal magnetic fields. Large portions of the atmosphere are in this state that is different from the quiet sun, sunspots, plages or

filaments and has not been modeled. Harvey also prepared an invited review on the subject "Chromospheric Magnetism."

Future Research Plans

During FY 2006, J. Harvey will continue to concentrate on development of SOLIS and GONG. He intends to try to do some science with these instruments if time permits. Harvey is collaborating with W. Livingston on a study of the strongest magnetic fields measured in sunspots during the last 90 years and with N.-E. Raouafi on a study of the roots of polar plumes using SOLIS data.

Service

J. Harvey retired as chair of the NSO/Kitt Peak Telescope Allocation Committee and NSO Scientific Personnel Committee. He continues service as a member of those committees and as SOLIS project scientist and GONG instrument scientist. Harvey also retired as co-editor of the journal *Solar Physics* in June 2005. He continued to serve on the National Research Council Associateship Review Panel but expects to retire from that position during FY 2006. Harvey served as a consultant for the Solar-B project at Lockheed-Martin.

Carl J. Henney, Associate Scientist

Areas of Interest

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

Recent Research Results

During the past year, Henney has continued to work on the calibration of solar activity forecast maps. In particular, he worked with S. Robbins (2004 NSO REU Student) and J. Harvey in the development of an empirical model to forecast high-speed solar wind using the location of coronal holes. This work was submitted to *Solar Physics* and is currently in press. Future forecasts are planned using daily coronal maps produced from a method for automated coronal hole detection developed by Henney in collaboration with J. Harvey using VSM He I 1083.0 nm spectroheliograms and photospheric magnetograms. In addition, Henney in collaboration with B. Durney addressed the question: Could reported periodicities of solar magnetic signals on time scales of two decades be the result of a purely stochastic process? To begin to answer this question, integrated full-disk solar time series created by a magnetic activity model using random eruptions were investigated. A surprisingly non-negligible likelihood is found, approximately 1 in 3, that observed periodicities from integrated full-disk solar parameters are a chance occurrence for time series on the order of 20 years in duration. Henney also continued collaboration with L. Bertello and R. Ulrich (UCLA) along with R. Garcia (CEA/DSM/DAPNIA) in the analysis of low frequency *p*-modes using the GOLF and MDI velocity time series.

Future Research Plans

The primary research tasks for Henney include the calibration of the VSM instrument, vector analysis, and cross-calibration of synoptic products with the KPVT. In addition, Henney will continue to calibrate various solar activity forecasting parameters derived from new VSM data products.

Service

As program scientist for the SOLIS project, Henney continued work on the development of C-based data reduction procedures for the Data Handling System (DHS) during the past year. He continued to develop and maintain the data reduction procedures for the production of SOLIS-VSM 630 and 854 nm longitudinal data products. The processing, in addition to the temporary storage and archiving, of the raw VSM spectral data was managed by Henney. He also worked on the development and implementation of the algorithms to apply longitudinal magnetic bias correction, along with geometric corrections to the VSM data products. Henney also continued to maintain and modify the synoptic data pipeline, previously designed for

KPVT data, to produce VSM synoptic products as part of the SOLIS DHS. In addition, he developed and maintained the SOLIS Web pages for public access to VSM data products, which include daily magnetograms and synoptic maps. Additionally, Henney continued collaboration with F. Hill and H. Jones in the development and management of the "Researching Active Solar Longitudes" (RASL) educational research project which is part of the "Data and Activities for Solar Learning" (DASL) project.

Frank Hill, Senior Scientist

Areas of Interest

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

Recent Research Results

Hill continues to perform research in helioseismology. Recent work with R. Howe, R. Komm, I. González-Hernández and others has provided new information on the fluid dynamics of the outer solar convection zone. The unprecedented temporal coverage of GONG has produced a five-year unbroken span of Carrington maps of the flows in the outer solar convection zone. A statistical study of this data set confirmed the existence of a strong correlation between horizontal vorticity below the surface, high magnetic field, and the level of flaring activity in an active region on the surface. These results point to a physical model of flares resulting from sub-surface "tornadoes", and could lead to a solar activity predictor.

Working with long-term visitor Kiran Jain, Hill has been comparing flow fields derived from helioseismology data obtained with different spectral lines. Using GONG data and data from the U Hawaii MOTH instrument, Jain and Hill are finding that the flows appear to be different when viewed in different spectral lines. Work is underway to understand the origin of the change, which needs to be understood before the launch of NASA's SDO mission.

Future Research Plans

Hill plans to probe the lower convection zone with large-aperture ring diagrams. These studies will be used to search for deep meridional flows required by current dynamo theories, as well as longitudinal structure of the tachocline, the region of the solar interior where the rotation profile changes from differential to solid-body. In addition, Hill will begin work on a direct 3-dimensional inversion of ring diagrams to estimate the vertical and horizontal flow fields in a self-consistent way. He also hopes to extend the modeling of the effect of spectral line profile changes on helioseismic inferences to include different atmospheric heights.

Service

Hill is the GONG program scientist and is managing the GONG Program. He also continues as the GONG data scientist, overseeing the development of algorithms for the reduction and analysis of data for helioseismology. Hill serves as the NSO digital library scientist, placing NSO and SOLIS data on-line and accessible over the Internet. He is participating in the development of the Virtual Solar Observatory, which was recently released to the public. He is also taking part in the Collaborative Sun-Earth Connection (CoSEC) project. Hill typically supervises several staff, currently seven scientists, one manager, and two programmers. He is a member of the IAU Working Group on International Data Access, and the NSO/Tucson Telescope Allocation Committee. He participates in the NOAO TLRBSE program, producing a software package to reduce and analyze McMath-Pierce NIM and NAC IR data.

Rachel Howe, Associate Scientist**Areas of Interest**

Helioseismology, the Solar Activity Cycle, Peak Fitting

Recent Research Results

In 2005, Howe published a paper on solar convection zone dynamics with F. Hill, R. Komm, and European colleagues. Further papers on this topic, in collaboration also with M. Rempel (HAO) and R. Ulrich (UCLA) are in preparation, and a paper on frequency variations in low-degree helioseismic frequencies has been submitted in collaboration with colleagues at the University of Birmingham, UK. Howe also presented work both global and local helioseismology at the SPD/AGU meeting in New Orleans. She also worked with R. Komm, F. Hill, and two summer students on aspects of local helioseismology, including possible flare predictors in local subsurface flows. A collaboration with colleagues at the University of Colorado on the variation of mode frequencies from local helioseismology is also ongoing. Howe visited HAO in Boulder, CO to give a seminar on convection-zone dynamics, and spent four weeks working with M. Thompson at the University of Sheffield, UK, on various aspects of helioseismic inversions. Howe is a co-investigator on the Helioseismic and Magnetic Imager (HMI) instrument to be launched aboard SDO (currently scheduled for launch in 2008) and as such attended the HMI team meeting at Stanford University in January 2005.

Future Research Plans

Howe intends to continue working on the above areas.

Service

In addition to the research activities described above, Howe shares with R. Komm the (informal) responsibility for checking the results of both the GONG PEAKFIND analysis and the 'ring diagram' pipeline that is currently under development. Howe also maintains the layout for the GONG resources CD, of which many copies were distributed at the 2005 AGU/SPD meeting. She chaired the SPD Popular Writing Award committee for 2005.

Stephen L. Keil, NSO Director**Areas of Interest**

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

Recent Research Results

Keil is collecting high-resolution measurements of solar granulation in quiet and active areas of the solar disk once or twice each year as part of a collaborative program led by Thierry Roudier (Obs. Pic-du-Midi). The goal is to look for changes in convective motions that follow the solar cycle. Once reduced, the data will be added to an archive, which includes data from several ground-based observatories. Keil recently participated in a joint observation program (JOP 178) with SOHO, TRACE, and several ground-based observatories to study the evolution and flows in regions beneath filaments to investigate conditions leading to the disruption of coronal mass ejections. A workshop on results from this work was held in May of 2005 in Paris. A second set of data was collected during a campaign in September of 2005 and is currently being studied.

Future Research Plans

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

Service

Keil is director of the National Solar Observatory and a member of the High Altitude Observatory advisory panel. He supervises both graduate and undergraduate students conducting research programs during the summer, and works closely with NSO and NOAO educational outreach programs. He served as chair of the NASA senior review of ongoing solar-terrestrial missions. He is a member of the AAS/SPD Prize Committee. Keil served on a panel to review the solar program in Sweden, including reviewing the productivity of the Swedish Solar Telescope and recommending its future course.

Shukirjon Kholikov, Assistant ScientistAreas of Interest

Helioseismology, Data Analysis Techniques, Time-Distance Methods

Recent Research Results

Shukur Kholikov works primarily on time-distance applications using GONG++ data and part of the time on running the farside image construction pipeline. He has developed a time-distance pipeline which provides travel-time maps of daily GONG-network data and produces reconstructed images with specified filters. One of the first results of time-distance analysis was measurements of travel time differences around sunspots using GONG data. Confirmation of depth dependence of these travel time differences for several active regions was obtained, and the results were presented at the SOHO14-GONG 2004 meeting. Kholikov introduced direct measurements of meridional circulation from spherical harmonic time series of the global pipeline. Preliminary results show very good agreement with MDI measurements.

Future Research Plans

Kholikov will continue to make improvements on the time-distance pipeline and provide the scientific community with specific GONG data for local helioseismology analysis. He will devote part of his time to longitudinal distribution of meridional circulation measurements.

Rudolf W. Komm, Associate ScientistAreas of Interest

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

Recent Research Results

Komm continues to perform research in helioseismology. He is deriving solar sub-surface fluid dynamics descriptors from GONG data analyzed with a ring-diagram technique (in collaboration with I. González-Hernández, F. Hill, R. Howe, and C. Toner). Using these descriptors, he was able to derive, for example, the kinetic helicity of solar sub-surface flows and study their relation to flare activity in active regions. He is studying the relationship between flare activity of active regions and the associated subsurface flows and conducted a survey of GONG and MDI data (in collaboration with his 2005 REU student, Douglas Mason). He is also studying the long-term variations of zonal and meridional flows in subsurface layers (in collaboration with Amel Zaatri, a summer graduate student he mentored in 2005).

Future Research Plans

Komm will continue to explore the dynamics of the near-surface layers and the interaction between magnetic flux and flows derived from ring-diagram data, and will focus on the relation between subsurface flow characteristics and flare activity in active regions. He will focus on daily variations of subsurface flows of selected active regions. In addition, he will compare subsurface flows derived from ring-diagram analysis with numerical simulations of these subsurface layers (in collaboration with S. Ustyugov, Moscow, Russia).

Service

Komm continues as coordinator of the Local Helioseismology Comparison Group (LoHCo).

John W. Leibacher, AstronomerAreas of Interest

Helioseismology, Atmospheric Dynamics

Recent Research Results

Leibacher's recent work has focused on the solar cycle variation of the eigen-frequencies, on which helioseismology is based, new techniques for measuring solar subsurface meridional circulation and its variation with the solar cycle, as well as the variation of the helioseismic signal with altitude in the solar atmosphere.

Future Research Plans

Ideas about the observational signature of the convective excitation of p -mode oscillations are being pursued with data from GONG as well as instruments onboard the SOHO spacecraft with collaborators at the Institut d'Astrophysique Spatiale (Orsay, France) and the Observatoire de Paris-Meudon, as well as the application of helioseismic techniques to stellar oscillations, in the framework of the CoRoT mission to be launched in 2006.

Service

Leibacher serves as co-editor of the NSO Newsletter, and as a member of the NSO Scientific Personnel Committee. He has been a mentor to an undergraduate physics student for three of the last four summers. He serves on the American Astronomical Society's Committee on Astronomy and Public Policy, as outgoing chair of the AAS's Solar Physics Division, and chairs the SPD summer school program, the bylaw update group, edits the SPD Directory, maintains the SolarNews WWW site. In 2005, he served as a member of the NAS/NRC Committee on PI-Led Missions, the NAS/NRC review of NASA's strategic roadmap, and as review coordinator of the NAS/NRC/SSB/CSSP review of NASA's vision for space exploration. He was a member of the NRL external review of their solar and space physics program. He co-organized the first SPD-sponsored summer school and the 2005 NSO summer workshop. He has initiated a project to translate *Project Astro* into Arabic, with colleagues in Tunisia, Algeria, and Morocco, and gives several "outreach" and broad overview talks on helioseismology and solar physics each year. In 2006 he is the co-organizer of the GONG/SOHO meeting in Sheffield (UK) and a Joint Discussion on helio- and asteroseismology at the IAU General Assembly. He is a co-editor of the journal *Solar Physics*.

Matthew J. Penn, Associate AstronomerAreas of Interest

Spectropolarimetry, Near-IR Instrumentation, Solar Atmosphere, Oscillations

Recent Research Results

An analysis of spectropolarimetric observations of sunspots at 1565 nm has yielded interesting observations of moving magnetic features within the sunspot penumbra. Such features have not been observed before, but data from the NSO/Kitt Peak McMath Pierce telescope covers a large time spans and shows evolution of the sunspot magnetic fields during several hours. This work was completed with the help of summer students from the University of Arizona and Cornell, and has been submitted for publication.

Future Research Plans

Penn is currently involved in vector magnetic field observations using the 1565nm infrared lines from the McM/P telescope. This line is very magnetically sensitive, and promises to reveal interesting new details of

the solar magnetic field and its evolution. Infrared molecular line observations are also being done in order to study details of the plasma conditions in sunspots, and polarimetry of spectral lines in the 3-5 micron wavelength range will be explored in the near future.

Service

Penn has recently taken first light spectra with the new NSO Array Camera (NAC) from 1083 to 4666nm. A new polarimeter for use from 1000-2500nm is being assembled, and options for polarimetry in the 3000-5000nm wavelength range are being studied. Penn is involved with the ATST development, particularly the IR and coronal aspects of the telescope. Work at the McMath/Pierce telescope with the NAC are intended to develop future science programs for the ATST. Penn has worked closely with University of Arizona undergraduate students as a faculty advisor for the ASTR 499 course, and by hiring UA students as part-time data aides. Penn is in charge of the NSO/Tucson summer REU program and works closely with the NSO staff to maintain the high quality of the NSO REU program. Penn participates in additional outreach activities through the TLRBSE and Science Olympiad programs in Tucson.

Alexei A. Pevtsov, Associate Astronomer

Areas of Interest

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

Recent Research Results

Pevtsov worked with researchers from other institutions on several studies including properties of X-ray and EUV bright points, properties of the sequential chromospheric brightenings, and comparison of helicity proxy α derived by different instruments. He also worked on a new method for the azimuth ambiguity resolution.

A case study of a transequatorial coronal mass ejection (CME) conducted in collaboration with K.S. Balasubramaniam, D. Neidig and researchers from other organizations led to a discovery of a new phenomenon, sequential chromospheric brightening (SCBs). It was found that SCBs may represent earlier stages of the chromospheric evaporation.

Pevtsov and his colleagues from Uzbekistan applied their previously developed automatic procedure to the entire SOHO/EIT dataset to study various properties of coronal bright points in different phases of solar activity cycle 23. A. Pevtsov and N. Karachik, NSO SRA from Uzbekistan, also studied rotation of solar corona using coronal bright points during deep minimum of sunspot activity. The differential rotation was found to be present in the corona at the height of formation of coronal bright points even when there was no sunspot activity. It was also shown that the coronal bright points situated inside coronal holes rotate with approximately the same rate as the bright points outside the coronal holes.

In collaboration with colleagues from China, Pevtsov has finished a comparative study of helicity proxy α , derived using data from two magnetographs: Haleakala Stokes Polarimeter and Solar Magnetic Field Telescope of Huairou Solar Observing Station. The results show relatively good agreement between the helicity proxies from two instruments, when a care is taken to account for a time variable noise and to exclude erroneous data. There was also found a clear dependence of an amplitude of helicity proxy (α) on the spatial resolution of an instrument.

Pevtsov developed a new method for 180-degree azimuth ambiguity resolution. The method is based on the assumption that at low spatial resolution the magnetic fields is well-represented by the potential model. In the

following steps, deviations from the potential field are gradually introduced until the final azimuths' ambiguity resolution is achieved.

Future Research Plans

A. Pevtsov plans to continue study the properties of X-ray and EUV bright points and associated photospheric bipoles. He also intends to study the role of complexity of magnetic fields in the coronal heating, and will continue his present work on the origin of periodic structures in quiescent prominences.

Service

In FY 2005, Pevtsov served as the supervisor for the NSO/SP technical library, participated in Sac Peak Telescope Allocation Committee (TAC), supervised PhD student from University of Alabama at Huntsville, and supervised the development of the Visible Light Broadband Imager (VLBI) for the ATST. He also participates in the ATST ASWG meetings. He served as the scientific supervisor for the NSF/NSO REU/RET programs, and supervised two NSO summer students (one REU and one SRA). He helped with digitizing the entire data set of historic CaK filtergrams from Evans facilities conducted by Dr. A. Tlatov, a visiting scientist from Russia. During FY 2005, he served as a reviewer for three professional journals (*Astrophysical Journal*, *Solar Physics*, and *Publ. of Astron. Soc. of Japan, PASJ*) and reviewed scientific proposals for the NSF and NASA. He also reviewed observing proposals for VLA. Pevtsov conducted several public tours at NSO/Sacramento Peak and gave three public lectures: one for the Southwest Montana Astronomical Society at the Museum of the Rockies in Bozeman, MT and two lectures at the Alamogordo Astronomy Club in Alamogordo, NM. He served as a co-editor for the ASP Conference Proceedings Series, vol. 346, and co-taught a graduate course on Observational Astrophysics at Montana State University in Bozeman, Montana.

Thomas R. Rimmele, Astronomer

Areas of Interest

Adaptive Optics, Multi-Conjugate Adaptive Optics (MCAO), Small-Scale Magnetic Fields, Active Region Dynamics, Flares, Acoustics Waves, Weak Fields

Recent Research Results

Rimmele published (*ApJ*) the analysis of diffraction-limited observations of G-band bright points. The program is aimed at understanding the basic physics of magnetic flux tubes. By exploiting the AO systems at the Dunn Solar Telescope, for which he is the PI, Rimmele published a paper on plasma flows observed in magnetic flux concentrations and sunspot fine-structure. He showed that strong and spatially narrow down flows are observed at the edge of magnetic structures such as small flux concentrations, pores and the sunspot umbra. He found strong evidence for what appears to be vigorous, small-scale convection in parts of the umbra and a light bridge-like structure in the observed sunspot.

Rimmele, along with the DLSP and AO teams, used adaptive optics and the diffraction-limited Stokes polarimeter to make diffraction-limited observations of an active region during the strong activity period in October-November of 2003. The observations included a small sunspot close to the limb on Oct 24 that was part of the region producing the X17.2 flare on October 28. A movie was produced showing a loop system eruption. It appears that the foot points of the loops, as well as some loop tops, become bright during the flare. The movie revealed, to our knowledge for the first time, flare structure at scales of 0.2 arcsec. The results were presented at the Denver SPD meeting. Rimmele was co-author on two papers on high-resolution flare observations performed at the DST with the high-order AO system.

Rimmele leads the NSO solar adaptive optics program and, in collaboration with NJIT/BBSO, has successfully completed the three-year program to build high-order AO systems for use on the 65-cm telescope at BBSO, and the Dunn Solar Telescope. The DST low-order AO system has been upgraded to a high-order

system. The NSF/MRI funded program also includes an effort to demonstrate the feasibility of solar MCAO. The NSO MCAO system was successfully locked on solar structure and its ability to correct an extended field of view (compared to conventional AO) was demonstrated.

Future Research Plans

Rimmele will continue his efforts to perform observations at the highest spatial resolution adaptive optics in order to study the properties and the dynamics of small-scale magnetic elements. Rimmele is working with M. Woodard (Colorado Research Associates) on understanding the physics of chromospheric K2V bright points and their relation to acoustic waves generated in intergranular lanes. Rimmele plans to publish the results of the diffraction-limited sunspot and flare observations (as time permits).

Service

Rimmele is project scientist for the Advanced Technology Solar Telescope Project, principal investigator of the NSF/MRI-funded Solar Adaptive Optics Program. Rimmele is chairing the ATST Science Working Group and is directing the ATST site survey effort. Rimmele is also the Dunn Solar Telescope program scientist. In this position he is responsible for all DST instrumentation and telescope upgrade projects and operations. He is directing the Sac Peak technical and operations teams. Rimmele prepared the science section of the ATST construction phase proposal. He supervises a PhD student (Jose Marino, NJIT) and worked with three other graduate students in summer 2005. Rimmele is Co-I on an MRI-funded project (with PI H. Lin (U. of Hawaii Institute for Astronomy)) to develop an infrared polarimeter for the DST and Solar-C on Haleakalā.

Clifford Toner, Associate Scientist

Areas of Interest

Global and Local Helioseismology, Image Restoration, Data Analysis Techniques

Recent Research Results

Toner completed automating the drift-scan processing. He has also automated the ftp transfer of MDI images from Stanford and the detection of bad/partial MDI images. As part of this process the MDI images are put into standard GONG orientation and the geometry header keywords are updated appropriately. Toner also completed a substantial redesign of COPIPE (Camera Offset PIPEline). The revised code uses all available noon-drift information and can use MDI images as a fiducial (if MDI data are available). The revised code has been used to obtain angles for all of the data recorded since the upgrade to GONG+. For a subset of these data (2003/11/18 through 2004/10/25) calculations were performed twice: once with MDI as a reference and all available noon drift information, and a second time using only the noon-drifts. Toner found that once five sites were recording noon drifts automatically the estimated angles determined by COPIPE were consistent, regardless of whether MDI data were included. Toner has recently begun work on revising the on-site code that produces the images used by the Farside project. The goal is to improve the quality of the on-site calibration, and hence improve the quality of the images that arrive in Tucson.

Future Research Plans

After completing and testing the modified on-site code, Toner will begin working on improving the magnetogram image merge.

Service

Toner performs observatory service as associate data scientist for the GONG program. He is also involved in the NSO Educational Outreach Program, having given talks and demonstrations at schools and at Boy/Cub Scout functions.

Han Uitenbroek, Associate Astronomer

Areas of Interest

Radiative Transfer Modeling, and Structure and Dynamics of the Solar Atmosphere

Recent Research Results

H. Uitenbroek continues to work on expanding and improving his multi-dimensional numerical radiative transfer code. The most recent additions include the capability to perform a Non-LTE solution for the full four-component Stokes vector in three-dimensional models, and the capability to calculate linear polarization due to continuum scattering processes. Improvements have been made in the way line broadening is treated.

There is a great need for techniques that can provide measurement of magnetic field strength in the solar chromosphere. Only a handful of spectral lines are sensitive to the field in these relatively poorly understood layers of the solar atmosphere. Among them are the Ca II infrared triplet lines the sodium D lines and the hydrogen H α line. Uitenbroek is performing forward modeling calculations in multi-dimensional simulations of solar magneto-convection to study the sensitivity of the Na I D lines and the Ca II infrared triplet lines to the chromospheric magnetic field. He is computing response functions, which provide a measure of the sensitivity of a spectral feature to given parameters in an atmospheric model, to estimate the heights in the solar atmosphere to which polarization signals in chromospheric lines are sensitive.

Comparison of the spatially averaged line profiles of chromospheric lines with calculated profiles from hydrostatic models shows that these lines have a strong red asymmetry in their cores. Even when the observed profiles are compared with spatially averaged profiles calculated through hydrodynamic simulations of the solar convection, this discrepancy remains. Possibly the red asymmetry is the result of acoustic waves steepening into shocks, the same mechanism that gives rise to the well-known K2V phenomenon in the Ca II K line. These waves are numerically suppressed in convection simulations and their contribution would not show up in the spectra calculated from the simulation snapshots. The observed redshift therefore further supports the notion of a very dynamic nature of the chromosphere.

Uitenbroek has obtained observations of the Ca II K line and 854.2 nm IR line at high spatial and spectral resolution in cooperation with Alexandra Tritschler at NSO and will compare these in detail with model simulations to discover the origin of the redshift.

Future Research Plans

In the coming year, Uitenbroek plans to continue with the development of his radiative transfer code. It will be used to further investigate the nature of G-band bright points, by calculating the G-band spectrum through two-and three-dimensional models of the solar convection and compare the computed contrasts with the best available imaging observations. The transfer code will also be used to investigate the viability of the calcium infrared triplet lines for chromospheric magnetic field measurements. The radiative transfer code will also be used to investigate the linear polarization properties of the NaI D lines due to scattering in cooperation with J. Trujillo Bueno (IAC, Spain).

Service

Uitenbroek serves as the chair of the Telescope Allocation Committee at Sac Peak, and also oversees the science exhibit in the Sunspot Visitor Center. He is the science lead for the Visible-light Broadband Imager (VBI) instrument for the ATST. About fifteen different researchers in different institutes, some even outside the field of solar physics, have requested copies of Uitenbroek's transfer code. He actively supports those users with updates and help running the code.

APPENDIX E: FACILITIES AND MAINTENANCE PLAN (FY 2006)

Facilities Maintenance

With the commissioning of the Advanced Technology Solar Telescope (ATST) between eight and twelve years away, NSO must continue to maintain a physical plant at two locations—Kitt Peak and Sacramento Peak. The current plan requires that we continue to support the community with first rate observing facilities until such time as the ATST becomes available for use. Inasmuch as a special appropriation has never been received to support this maintenance, the facilities must be maintained in good repair through regular allocations of funding. In addition, to regularly schedule maintenance each year, the issues of deferred maintenance are addressed. Deferred maintenance is defined as maintenance that should be regularly scheduled at intervals longer than one year to keep buildings in good working order and to prevent deterioration of the physical plant but yet is frequently postponed due to funding or priority issues. Deferred maintenance does not include the costs of upgrading facilities—e.g., providing high bandwidth wiring to support computer networks.

The current budgets for the National Solar Observatory remain insufficient to provide for an optimum maintenance program of the facilities at Sac Peak and Kitt Peak. There are, however, sufficient funds to carry out essential maintenance. Year-end funds, to the extent that they become available from vacant positions or indirect charges on grants, are used to supplement this minimum maintenance program. This minimum program will continue until the deployment of the ATST and the disposition of Sac Peak and Kitt Peak facilities. FY 2006 facilities maintenance projects at each site are described below.

Sacramento Peak

The FY 2006 program plan budget for NSO/SP expected approximately \$40K in funds above our normal reactive maintenance program and some amount of carryover from the previous fiscal year. We were able to accomplish several items on our list of projects, however increasing fuel costs did absorb much of those funds. For FY 2006, our carryover is approximately \$10K. With the continuing rise in propane costs, our maintenance budget will be very tight this year. Any funds in excess of our normal maintenance will be reserved for any improvements required of our sewage plant for renew of our State Environmental Department permit. Smaller projects that will be undertaken as funding permits include continued repainting of commercial buildings and residences, upgrade of our above ground petroleum storage tanks and the replacement of one of our staff vehicles. In addition, the Long-Range Plan lists as other maintenance tasks such as the demolishing of the Cloudcroft facility/RCA building. This is an item that has been deferred for several years. Although important, funding availability and priorities have not allowed completion of this item. We will continue to monitor this situation and other deferred items and will accomplish them whenever possible.

Table E-1. NSO/Sac Peak Summary of FY 2006 Projects

(Dollars in Thousands)

<i>Project</i>	<i>Est Cost</i>
Sewage Plant Upgrade	50
Above Ground Petroleum Storage Upgrade	13
Commercial Painting	10
Housing Painting	10
Vehicle Replacements	25
Cloudcroft Facility	50
Total	\$ 158

Sewage Plant Renovation: The sewage plant that treats all the sewage generated at Sac Peak must be re-permitted in 2006. Changes in the requirements established for the facility may require a substantial upgrade. Significant improvements were made in FY 2005. Funds will be reserved to assist in this upgrade.

Petroleum Storage Tanks: Our above ground storage tanks require upgrading to meet current State and Federal standards. Upgrades include removal of 2 single-wall tanks and buried lines and the installation of new above ground lines from our vaulted tanks to the emergency generators. Other than the sewage plant renovation, this is our highest priority project.

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

Cloudcroft Facility: The RCA building and a office trailer, are in poor condition and require attention. The RCA Building will cost approximately \$50K to demolish. Upon approval by the NSF, our staff will demolish the trailer and have it hauled away. This will remove an ongoing maintenance and potential safety problem.

Housing Painting: Approximately 1/3 of the residences were repainted last summer. If funds permit, summer helpers will be hired again this year and they will continue this project.

Vehicle Replacements: Our vehicle replacement plan includes the need to replace one of our staff vehicles.

Accomplished in FY 2005:

- Replaced the purchasing van
- Initiated renovation/upgrade of sewage
- Upgraded the cable television system
- Completed the exterior painting of several commercial buildings and residences
- Replaced the uninterruptible power supply at the DST

Kitt Peak

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

The first priority maintenance item that also enhances the scientific effectiveness of our new instrumentation is the upgrade of the Telescope Control System (TCS) for the McMath-Pierce (McMP) Solar Telescope. We have pursued the TCS upgrade as a project but it has since become a critical maintenance issue for the continued operation of the telescope.

Background

The McMP facility provides a complement of modern post-focus instruments. Recently, a 37-actuator adaptive optics system has been added, and a versatile, large-format infrared camera will become operational in 2005. The control system was last upgraded in the 1970s to a computer-driven telescope control system. The out-dated electronics are increasingly prone to failures as spare parts and knowledgeable technicians are becoming scarce to non-existent. Operation of the McMP has become dangerously dependent on old systems

that are becoming, or have become, unsupportable. The installation of a modern TCS is urgently needed to assure the continued operation of the McMath-Pierce telescope until the ATST can carry on the crucial solar research currently limited to the McMP facility. Otherwise, failure of antiquated parts is expected to lead to extended downtime periods within the next two years, which is scientifically unacceptable. The major critical, non-supportable items that need to be replaced are:

- The TCS Computer, a vintage PDP-11/73 mini-computer running Kitt Peak Multitasking Forth.
- The Telescope Interface Control (TIC). The TIC interfaces between the TCS and the telescope drives, encoders, etc. through a CAMAC electronics chassis and mechanical relay racks. Replacement parts for CAMAC are no longer available. Repairs must often be made at the component level. The 40-year old mechanical relays that control the telescope mirror movements are becoming unreliable.

The primary motivation for the TCS upgrade is increasing the reliability and maintainability of the system. The expected enhanced scientific capabilities are a natural consequence of modern computer hardware and software. The new TCS will be able to move to arbitrary coordinates on and off the solar disk providing accurate spatial coordination with other solar facilities on the ground and in space. It is expected that the McMP will also implement a CCD guider system, which will provide updates to the TCS tracking and pointing routines, and may also provide real-time images for use in target selection by observers at the telescope. The TCS will also interface with focal plane instrumentation to allow raster scanning of regions of interest in synchrony with the data collection.

Outsourcing is the most economical approach to upgrading the McMP TCS. NSO has previously outsourced the highly successful upgrade of the McMP East Auxiliary telescope. Several companies have ample experience with such projects and can provide turnkey systems based on their existing TCS products. This minimizes up-front costs and maximizes the availability of replacement parts and knowledge for maintenance. The estimated cost is in the approximate range of \$250K-\$300K.

The other deferred maintenance items that have appeared in past Program Plans are still required but are secondary to the needed TCS upgrade. If the TCS is not upgraded, then the remaining maintenance items become superfluous.

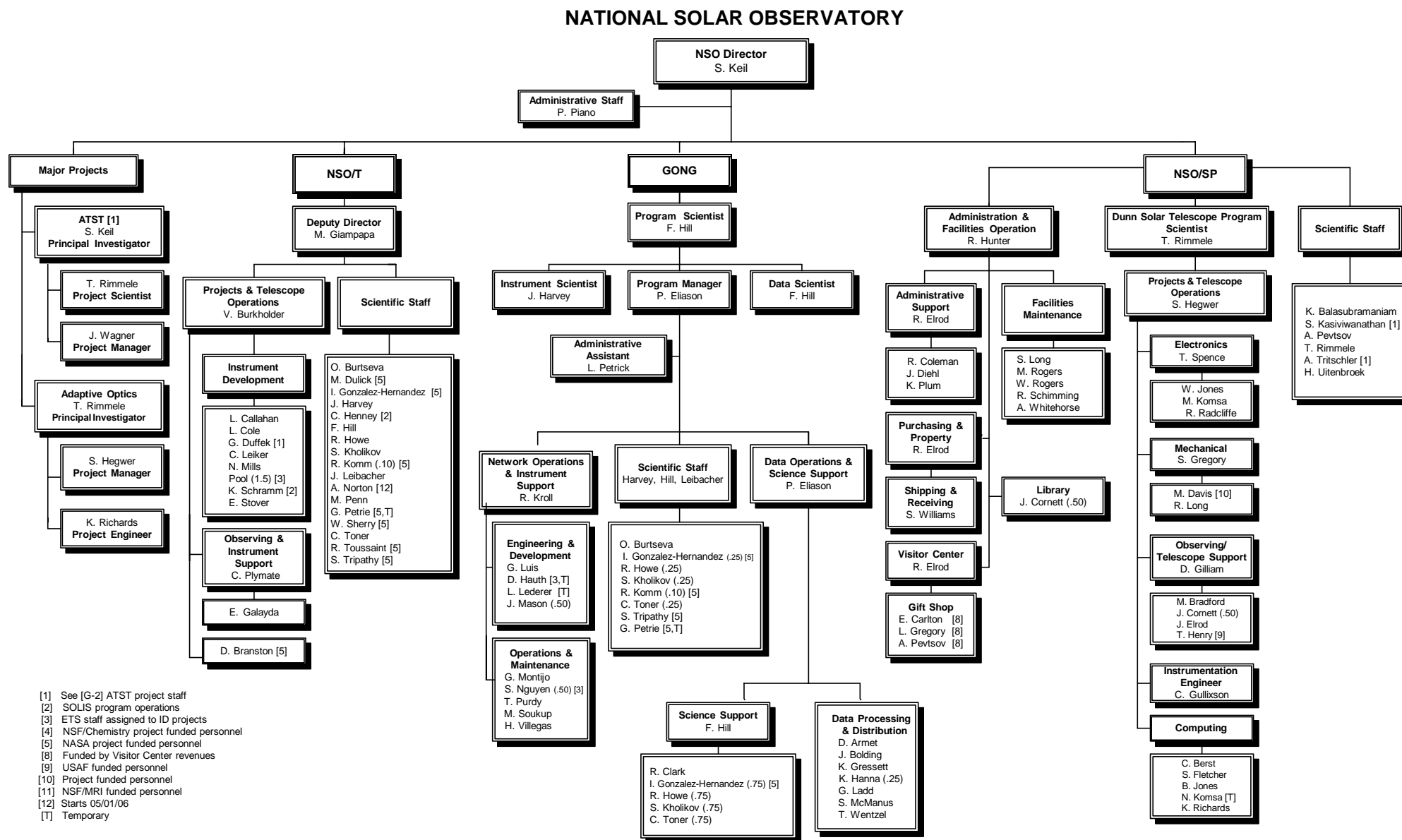
APPENDIX F: NSO MANAGEMENT

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 Program 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
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

APPENDIX G: ORGANIZATIONAL CHARTS

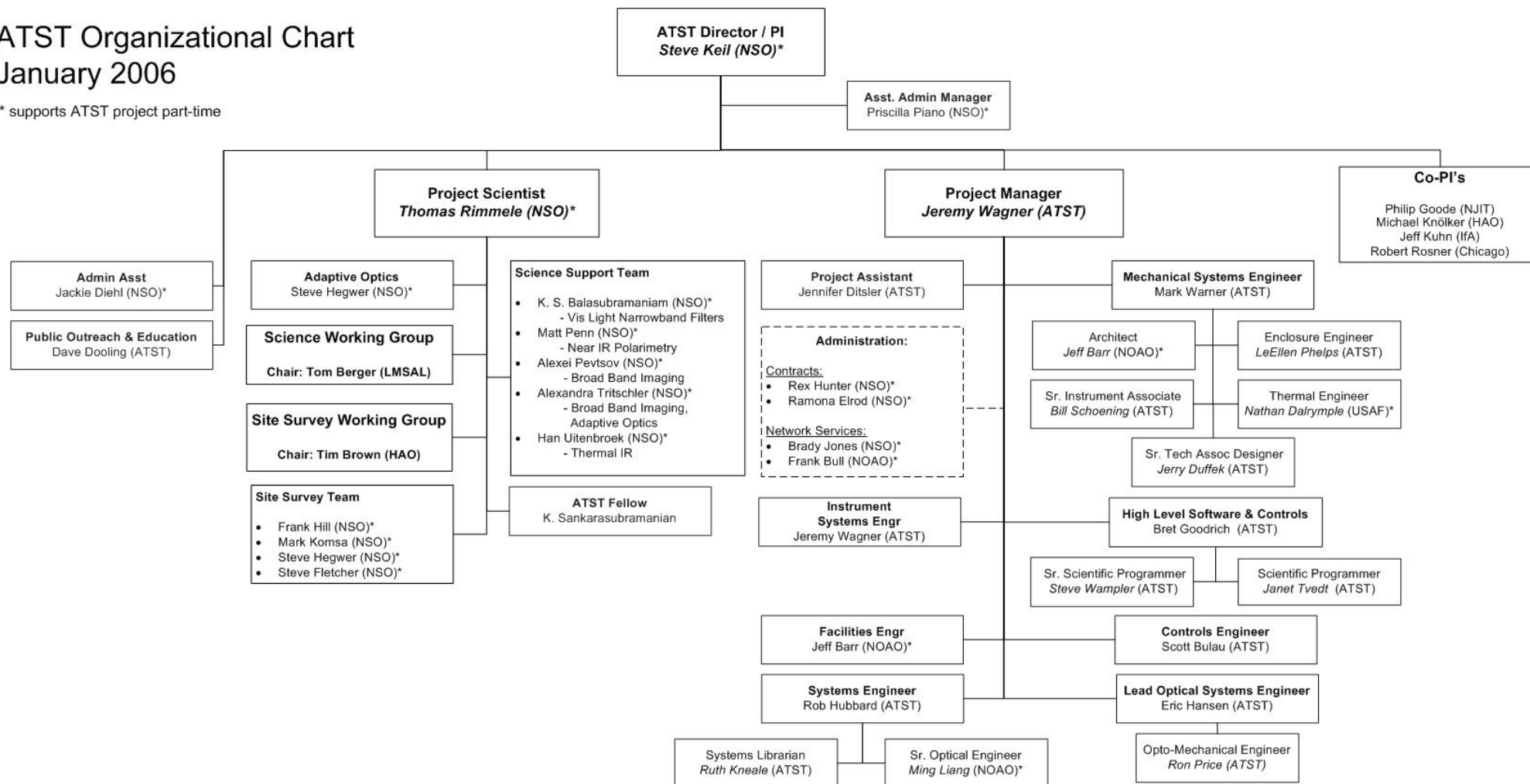


- [1] See [G-2] ATST project staff
 [2] SOLIS program operations
 [3] ETS staff assigned to ID projects
 [4] NSF/Chemistry project funded personnel
 [5] NASA project funded personnel
 [8] Funded by Visitor Center revenues
 [9] USAF funded personnel
 [10] Project funded personnel
 [11] NSF/MRI funded personnel
 [12] Starts 05/01/06
 [T] Temporary

ATST Organizational Chart

January 2006

* supports ATST project part-time



APPENDIX H: ACRONYM GLOSSARY

AASC	Astronomy and Astrophysics Survey Committee
AAS	American Astronomical Society
AFRL	Air Force Research Laboratory
AO	Adaptive Optics
AO76	Adaptive Optics system with 76 degrees of freedom
ARs	Active Regions
ASP	Advanced Stokes Polarimeter
ASWG	ATST Science Working Group
ATST	Advanced Technology Solar Telescope
AURA	Association of Universities for Research in Astronomy, Inc.
BBSO	Big Bear Solar Observatory
BP	Bright Points
CCD	Charged Couple Device
CD-ROM	Compact Disk – Read Only Memory
CfAO	Center for Adaptive Optics
CFD	Computational Fluid Dynamics
CNES	Centre National d’Etudes Spatiales
CoDR	Concept Design Review
CoRoT	COncvection, ROtation and Transits (ESA/CNES space mission)
COPIPE	Camera Offset PIPEline (GONG)
CoSEC	Collaborative Sun-Earth Connection
CSSP	Council of Scientific Society Presidents
CSUN	California State University, Northridge
DASL	Data and Activities for Solar Learning
DHS	Data Handling System
DMAC	Data Management and Analysis Center
DRD	Design Requirements Document
DST	Dunn Solar Telescope
EGSO	European Grid of Solar Observations
EIS	Environmental Impact Statement
EPO	Educational and Public Outreach
ESA	European Space Agency
ESF	Evans Solar Facility
ETH-Zürich	<i>Eidgenössische Technische Hochschule- Zürich</i>
EUV	Extreme Ultraviolet
F&A	Facilities & Administration (AURA Fee)
FASR	Frequency Agile Solar Radiotelescope
FDP	Full-Disk Patrol
FOV	Field of View
FP	Fabry-Perot
FTS	Fourier Transform Spectrometer
FY	Fiscal Year
GA	Genetic Algorithms
GB	Giga Bytes
GONG	Global Oscillation Network Group

APPENDIX H: ACRONYM GLOSSARY

GOLF	Global Oscillations at Low Frequencies
GSFC	Goddard Space Flight Center
HAO	High Altitude Observatory
HMI	Helioseismic and Magnetic Imager (SDO Instrument)
HT	Hilltop Telescope
IAC	<i>Instituto de Astrofísica de Canarias</i> (Tenerife, Spain)
IBIS	Italian BI-dimensional Spectrometer
ICC	Instrument Computer Control
ICD	Interface Control Document
IFA	Institute for Astronomy (University of Hawaii)
IHY	International Heliophysical Year
IR	Infrared
IRAF	Image Reduction and Analysis Facility (NOAO)
ISOON	Improved Solar Observing Optical Network
ISS	Integrated Sunlight Spectrometer
KHD	Kinetic Helicity Density
KIS	Kiepenheuer Institute for Solar Physics
KPNO	Kitt Peak National Observatory
KPST	Kitt Peak SOLIS Tower
KPVT	Kitt Peak Vacuum Telescope
LTE	Local Thermal Equilibrium
LWS	Living With a Star (NASA)
LoHCo	Local Helioseismology Comparison Group
MDI	Michelson Doppler Imager
MEMS	Micro-Electro-Mechanical System
MHD	Magnetohydrodynamic
MKIR	Mauna Kea Infrared
MREFC	Major Research Equipment Facilities Construction
MRI	Major Research Instrumentation (NSF)
NAC	NSO Array Camera
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NEO	Near-Earth Object
NJIT	New Jersey Institute of Technology
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NOAO/ETS	National Optical Astronomy Observatory/Engineering and Technical Services
NRC	National Research Council
NSB	National Science Board (NSF)
NSF	National Science Foundation
NSF/AST	National Science Foundation, Division of Astronomical Sciences
NSF/ATI	National Science Foundation, Advanced Technology and Instrumentation
NSF/ATM	National Science Foundation, Division of Atmospheric Sciences
NSO	National Solar Observatory
NSO/SP	National Solar Observatory Sacramento Peak
NSO/T	National Solar Observatory Tucson

APPENDIX H: ACRONYM GLOSSARY

PAEO	Public Affairs and Educational Outreach
PCA	Principal Component Analysis
PSF	Point Spread Function
QSA	Quasi-static Alignment
RASL	Research in Active Solar Longitudes
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
SCOPE	Southwest Consortium of Observatories for Public Education
SDO	Solar Dynamics Observatory
SDR	Systems Design Review
SOHO	Solar and Heliospheric Observatory
SOI/MDI	Solar Oscillations Investigations/Michelson Doppler Imager (SOHO)
SOLIS	Synoptic Optical Long-term Investigations of the Sun
SPD	Solar Physics Division
SPINOR	Spectropolarimeter for Infrared and Optical Regions
SRA	Summer Research Assistant
SRD	Science Requirements Document
SSB	Space Science Board
SXT	Soft X-ray Telescope (<i>Yohkoh</i>)
TAC	Telescope Allocation Committee
TB	Tera Bytes
TCS	Telescope Control System
TL	Transequatorial Loop
TLRBSE	Teacher Leaders in Research-Based Science Education
TON	Taiwan Oscillation Network
TRACE	Transition Region and Coronal Explorer
UBF	Universal Birefringent
UCSD	University of California, San Diego
UV	Ultraviolet
VBI	Visible-light Broadband Imager (ATST)
VMG	Vector Magnetograph
VSM	Vector Spectromagnetograph
VSO	Virtual Solar Observatory
WBS	Work Breakdown Structure
WWW	World Wide Web
<i>Yohkoh</i>	“Sunbeam,” Satellite project of the Japanese Institute of Space and Astronautical Sciences
ZIMPOL	Zürich IMaging POLarimeter