

NATIONAL SOLAR OBSERVATORY



NSO Annual Program Plan FY 2005

Submitted to the National Science Foundation under Cooperative Agreement No.
AST-0132798 (SPO NO. 2)

Also published on the NSO Web site: <http://www.nso.edu>



The National Solar Observatory (NSO) is operated by the Association of Universities for Research in Astronomy (AURA) Inc., under a cooperative agreement with the National Science Foundation (NSF).

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;
- Expanding the NSO current solar adaptive optics (AO) program to achieve diffraction-limited imaging at solar telescopes at NSO and at other institutions, and to develop the 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 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 2005 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 2005 with the \$10,720K budgeted by the NSF Astronomy Division for solar physics and with the additional funds received from NSO's partnering organizations. The plan also discusses how the 2005 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.

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 2004, the ATST construction phase proposal was submitted and reviewed at the NSF, with the review panel as well as the write-in reviewers giving the proposal excellent marks in all areas. The panel strongly recommended that NSF support the project and pursue construction of the ATST as soon as possible. The project was forewarned by the NSF that the earliest start of construction would be in 2007 (or perhaps later), if included in the Major Research Equipment Facilities Construction (MREFC) funding line. Given that the design and development (D&D) phase proposal covers only the 2001-2005 period, the project is now working with the NSF to identify funds for continuing development in 2006 to facilitate a smooth transition to construction in 2007.

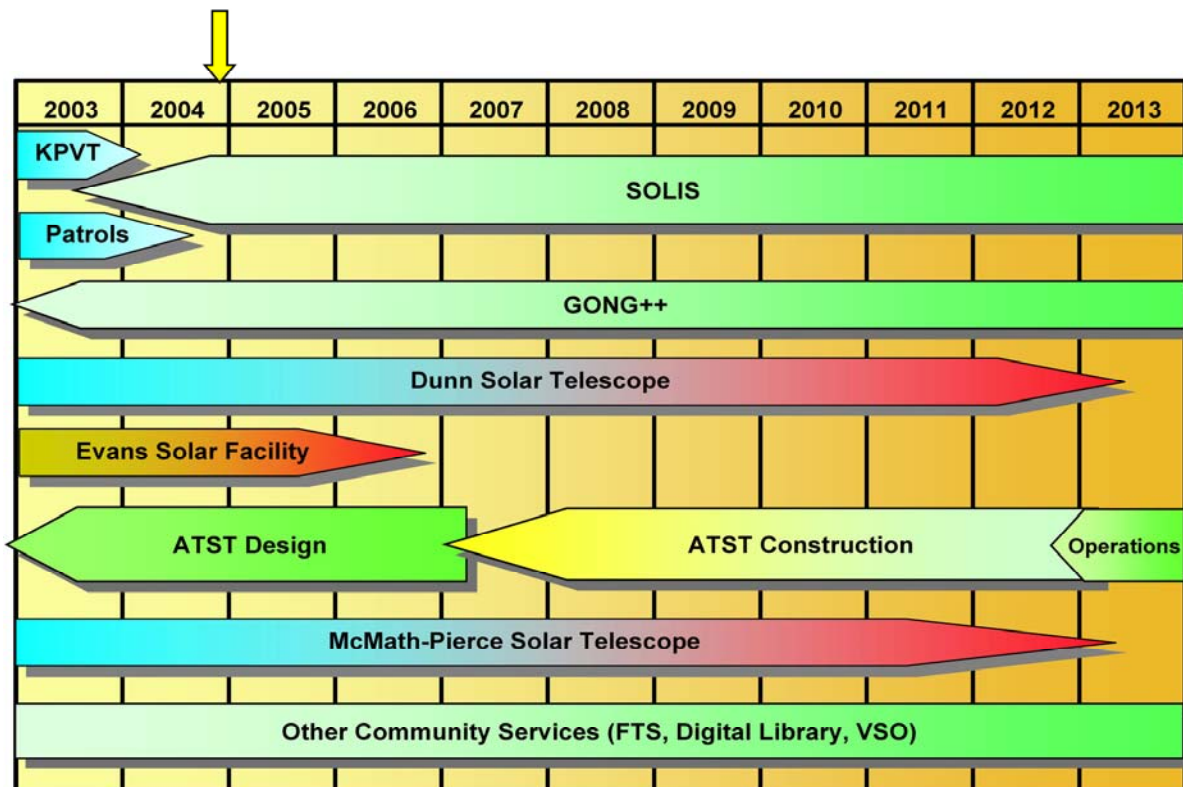


Figure II-1. Strategic Road Map of NSO Facilities

During the past year, the adaptive optics program continued to develop user friendly software and interfaced the AO systems with new diffraction-limited instrumentation. In addition, a series of successful multi-conjugate AO experiments have been conducted that will lead the way to MCAO at the Dunn Solar Telescope (DST) and to an MCAO upgrade design for the ATST. A testing and debugging phase was conducted for the SOLIS Vector Spectromagnetograph (VSM), which is now installed on Kitt Peak and making synoptic observations, providing data to the community via the NSO Digital Library and the emerging Virtual Solar Observatory (VSO). The other SOLIS instruments, the Integrated Sunlight Spectrometer (ISS) and Full-Disk Patrol (FDP), will come online in the next few months. GONG continued operating with its new high-resolution cameras and implemented routine far-side imaging and near-real-time magnetic field maps, which have application 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

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. 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>.

Highlights from this past year include completion of a two-part instrumentation conceptual design review (CoDR), completing the phase-one enclosure vendor design and analysis at M3 Engineering, the Site Survey Working Group (SSWG) submission of its final site survey report, and the Science Working Group (SWG) recommendation of primary and alternate sites. 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.

1.1.1 ATST Organization and Progress

The major change to the ATST project organization over the past year was the departure of Project Manager Jim Oschmann. After leading the engineering team through a successful conceptual design

review and submission of the management and technical sections of the construction phase proposal in January 2004, Oschmann accepted a position in July with Ball Aerospace in Boulder, Colorado. A project manager search committee was established shortly thereafter. Several qualified candidates were interviewed and, on December 10, 2004, Deputy Project Manager Jeremy Wagner was named as project manager.

The engineering team reports to the project manager and the science team to Thomas Rimmele. NSO Director Steve Keil is the ATST project director.

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 site survey have been established through Memoranda of Understanding.

The current ATST organization is shown in Appendix G. People with NSO or USAF designations are being contributed to ATST from NSO base funds or USAF funds. Others within the NSO are contributing to the design and organization. There are planned additions to the ATST NSO staff for adaptive optics, electronics, and other areas as needed.

The first major milestone of the year was submission of the construction phase proposal, which included a detailed technical description of the ATST. Preparation of the technical description was led by the project's systems engineer and input to the description was provided by the entire engineering team. Design activities during the past year were focused on completing follow-up activities from the CoDR committee recommendations, refining engineering flow-down of requirements, performance modeling, and related activities leading to the Systems Design Review (SDR) scheduled for March 2005.

The design efforts have focused on the enclosure ventilation and thermal control, coude platform simplification, M1 thermal control performance and instrumentation development, and integration with the systems design.

For most of the year, project efforts concentrated on the enclosure design and its ventilation and thermal control. The current design is shown in Figure II-2. This enclosure design is a co-rotating ventilated dome with external skin cooling. A ventilated dome allows the ability to minimize primary mirror, telescope structure, and internal dome air seeing, while having the flexibility to control telescope shake and mirror buffeting during high wind conditions. This design is used for all newer, large nighttime telescopes, but presents a new challenge for daytime viewing. During the day, the Sun will heat the dome structure unless it is actively cooled. The ATST enclosure design pays particular attention to thermal control and ventilation details and ensures that the dome will have minimum impacts on local seeing. A computational fluid dynamics (CFD) analysis of the enclosure design has been completed and the results are satisfactory for optimizing dome ventilation. M3 Engineering was placed under contract to evaluate and analyze the thermal control of the enclosure design. M3 completed their work and presented a final report at a review held in Tucson in October 2004.

In parallel, thermal control concepts for the primary mirror and other optics have evolved, with concentration on the primary and secondary mirrors. The thermal models have been updated to include seeing effects based upon work by Nathan Dalrymple (USAF/AFRL). These models were also extended to



Figure II-2. *Current ATST layout design.*

apply to mount and dome-shell seeing. The latter are the primary technical concerns of efforts leading to the Systems Design Review.

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). Xinetics was placed under contract to analyze the thermal control requirements for the DM concept. Other AO-related work has concentrated on identifying and defining the interfaces between the adaptive optics, active optics, guiding, and software control systems.

Work on the telescope mount has included refinement of the design using input from the completed finite-element analysis of flexure and windshake, assuming a loose soil configuration. Details of the coude lab design have evolved and a great deal of simplification has been done along with analysis of tolerances with respect to the optics.

To allocate requirements and assess performance at a systems level, the ATST systems engineer has made significant progress on the error budget for several key cases, including bottom-up performance modeling that includes statistical input from the sites in the area of seeing, wind, and thermal properties. Tying

these with Nathan Dalrymple's thermal modeling of the M1 assembly is providing a good assessment of the range of likely performance that is guiding the design efforts.

1.1.2 ATST Site Selection

The ATST Site Survey Working Group, with broad community participation, was very active this past year. This committee has representatives from current collaborators and other nations that have expressed interest in participating in the ATST. As of December 2004, the following have been accomplished:

- Phase II of the ATST site survey at the three finalist sites was completed in September 2004.
- The SSWG presented their final report to Project Scientist Thomas Rimmele in early October 2004.

The Science Working Group, chaired by the project scientist, met in October 2004 to review the final SSWG report. The SWG prepared and submitted to the director their recommendation for the primary site and alternate sites on the basis of the sites' scientific quality. The SWG recommended Haleakala as the primary site. Final endorsement by AURA of this recommendation will occur in early 2005.

1.1.3 Near-Term Plans

Following the work breakdown structure (WBS) and schedule for the design and development phase, the project will continue its design efforts in preparation for the preliminary design reviews. This will include the involvement of industry in the preliminary designs and working with the partnership through established work packages for instrumentation and site survey completion.

Project plans for FY 2005 begin with convening the Systems Design Review in March 2005. The SDR will cover the impact of the selected primary site on designs, cost estimates and planning. This includes requirements flow down, performance modeling, interface control, and overall design status. The project efforts during the remainder of 2005 will focus on the preliminary design. The work breakdown structure, planning, and schedule for the construction phase presented in the construction phase proposal are also being 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. Contingency will be held centrally. Prioritization of tasks will be based on feedback from the SDR, Science Working Group review of the SDR, and contractor feedback. The project budget status will determine the extent to which major contractors will be utilized throughout this phase.

Instrumentation designs will evolve, again concentrating on impacts to the facility design. With the selection of the primary site in December 2004, environmental impact assessments will be initiated for the primary site, and detailed building designs will commence by spring 2005.

With science objectives in mind, key observing scenarios will be worked out to better understand and develop operations planning. The plan calls for two major reviews to be held during the design and development phase. These include:

- Systems Design Review (2005)
 - Systems-level design of the baseline approach established after the conceptual design phase.
 - Requirements flow down.

- Interface definition and control.
- Instrument integration and operational considerations.
- Involvement of partner and manufacturing organizations in the process where possible.
- Critical Design Review (2006)
 - Preparing construction detailed design and specifications.
 - Procurement planning.
 - Integration, test and commissioning planning.
 - Operational planning.

One or two additional workshops involving partners and community representatives will likely be held as the system design evolves over the next two years.

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

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

Table VI-10 in Section VI on Management and Budget shows the breakdown of the \$2.4M NSO expects to receive from NSF/AST and the \$13K from NSF/ATM as part of the ongoing D&D Phase. This brings the total D&D funding received from NSF to \$11.8M. If the project does not start most of the planned contractual design efforts, this amount will carry the design team through FY 2005 and through most of FY 2006. However, delaying the final design contracts creates risk. Limited industrial involvement at this stage will make more redesign by contractors necessary. This will drive increased construction costs or force some descope of capabilities and slow down the schedule as submitted in the construction phase proposal.

The provided D&D funding did not include funds to bring the designs to the final design level. We had therefore originally anticipated completing the design effort after the beginning of MREFC funding in FY 2006. Our planning now takes into account a delay in the start of construction to FY 2007. Current estimates for what is required for construction readiness were developed after completion of the D&D Conceptual Design phase and CoDR. This systems-engineering phase included rigorous requirements identification, analysis, and flow down to design requirements. Qualified and experienced vendors were contracted to perform design evaluation and feasibility studies which included costing. Estimates for the design completion efforts by vendors were higher than those included in the original D&D proposal. These estimates, together with the construction start delay to FY 2007, form the basis of the additional funds required for completion of the D&D phase.

The NSF asked the project to provide an estimate of the funding needed to bridge FY 2006 with a smooth transition to construction in FY 2007. NSO submitted a plan outlining options for funding and levels of vendor involvement. A summary of those options follows.

No additional funding for D&D beyond FY 2005: This option assumes that funding to build the ATST would begin in FY 2007. It also assumes that the last increment for D&D is the planned \$2.4M in FY 2005, bringing the total D&D funding to \$11.8M. In this case, the project would have only a limited amount of money to begin contractor design participation. We would delay the start of most of the

planned vendor contractual efforts needed to design ATST subassemblies, and the current ATST staff would be used to make progress on designs in critical areas. At the Systems Design Review planned for March 2005, the project would carefully assess which of the planned vendor efforts have the most impact on cost and schedule, and the limited resources would be devoted to these areas. The impact would be that final designs in major areas that require considerable contractor involvement, such as the enclosure, telescope assembly and M1 assembly, would need to wait for funding needed to build the ATST. Although the construction phase proposal did include some design completion costs to cover fabrication drawings as well as some potential design rework, additional funds are required to begin vendor contracts and bring the designs to a level where fabrication drawings can be made. In order to fund the design team for most of FY 2006 with this option, vendor contracts must be delayed. Delaying the final design contracts creates risk. Limited industrial involvement at this stage would result in additional redesign by contractors which will drive increased construction costs, or force the descope of capabilities and slow down the schedule as submitted in the construction phase proposal.

NSF provides an additional \$2M in FY 2006: This scenario assumes that the project will receive the \$2.4M increment planned for FY 2005 and bridging funds of \$2M in FY 2006. It also assumes that construction would begin in FY 2007. In this case, we have considered two possible options. In the first option, we would not start any large vendor contracts but would increase in-house design efforts through additional hires. This would permit us to advance closer to final design than in the scenario above, but carries much of the same risk in terms of redesign when construction contracts are put in place. Other issues include the fact that the design costs required to get to the same level of design completion are unlikely to be lower with an in-house effort. Also, additional staff will increase personnel costs in the case of a further delay in the construction start.

A second option in this funding scenario is that we ask contractors to do what they can with the money available. This would support about 25% of the contractor estimates for completing the designs. Because of the uncertainty in continued contractual funding, we would need to select single contractors with optional design completion and fabrication phases. This would very likely add to the overall cost, as the packages would be less attractive to bidders. However, by involving at least a portion of the contractors earlier, this option would mitigate some of impact on the construction budget and schedule by eliminating some of the need for redesign. We would select which contracts to initiate, following the Systems Level Design review in March. For example, a contract for the system that encompasses the M1 and M2 assemblies would be a good candidate for moving forward in this option.

Any increase in the amount of funding provided by NSF in FY 2005 or FY 2006 would allow us to start more of the design efforts planned for vendors. For example, at the \$4M FY 2006 increment outlined in the NSO Long-Range Plan, we could support about 50% of the contractor estimates for completing the designs.

An optimum scenario: This scenario assumes that the project will receive the \$2.4M increment planned for FY 2005, as well as an additional FY 2005 increment of \$2.3M and a FY 2006 increment of approximately \$7M. This scenario also assumes that construction would begin in FY 2007. The increments would cover an additional year of D&D personnel costs at ~\$1.7M and supporting non-payroll at \$669K for FY 2006. To support the inclusion of contractors in the systems-level design efforts to PDR, \$2.3M of additional fund would be required in FY 2005. The additional \$4.2M in FY 2006

above personnel costs would bring the designs to CDR level. This would allow us to be ready at the appropriate level of design and vendor involvement for full start of construction in FY 2007. This optimum scenario supports the most efficient handover to major contractors while minimizing the risk of paying for the detailed design effort twice. Little cost or schedule impact to construction would be expected. We have included in this estimate the worst-case estimate for the environmental impact studies at Haleakala, an additional \$550K. Establishing vendor design completion contracts in FY2005 and FY2006 ensures a smooth transition from the D&D phase to construction, minimizing impact on the cost and schedule presented in the construction proposal.

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.

NSO, in primary partnership with the New Jersey Institute of Technology (NJIT), has developed high-order solar adaptive optics for use at the 65-cm telescope at Big Bear Solar Observatory (BBSO) and the 76-cm Dunn Solar Telescope (DST) at Sacramento Peak. The National Science Foundation has sponsored this project within the Major Research Instrumentation (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.

After commissioning of the first high-order AO system at the DST during FY 2004, the low-order AO system at the DST has been upgraded to a high-order AO system. The DST now provides two identical AO systems, well matched to the seeing conditions at the DST and feeding two different instrument ports that can accommodate a variety of facility-class instrumentation, such as the Diffraction-Limited Spectro-Polarimeter (DLSP) and the new Spectropolarimeter for Infrared and Optical Regions (SPINOR), as well as experimental setups and visitor instruments such as the Italian BI-dimensional Spectrometer (IBIS). The BBSO AO system was deployed in December 2003. The NSO AO team integrated the AO system into the BBSO optical setup and closed the servo loop at BBSO.

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 (PSF), 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. In collaboration with the Center for Adaptive Optics (CfAO) and researchers at the Herzberg Institute in Canada, the PSF estimation tools were developed by a graduate student during FY 2004. The student is now applying the computed PSFs to reconstruct an excellent time sequence of UBF filtergrams.

The AO project is now focused on the development of multi-conjugate adaptive optics (MCAO). 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. An MCAO proof-of-concept experiment was successfully performed at the DST using the two existing deformable mirrors placed at conjugates of two different altitudes in the atmosphere. The control loop was closed on three “guide stars.”

Initial evaluation of imaging data recorded during the observing run clearly shows an extended correct field of view compared to the conventional AO case. Several MCAO observing runs are planned for FY 2005 in order to perform a more detailed performance evaluation of the system and to optimize the system as needed.

The project will continue to work closely with other MCAO efforts at such institutions as the Kiepenheuer Institute, the National Optical Astronomy Observatory (NOAO), the Center for Adaptive Optics, and the Gemini Observatory.

2 Instrumentation Program

2.1 Dunn Solar Telescope (DST)

The instrumentation development plan for the DST includes several new major instruments. These new instruments will provide new and/or enhanced capabilities to the users and, in addition, serve as test beds for ATST instrumentation concepts and components.

2.1.1 Diffraction-Limited Spectro-Polarimeter (DLSP)

The Diffraction-Limited Spectro-Polarimeter is a collaborative project between the High Altitude Observatory and NSO. The DLSP will permit different image scales, from high-resolution (at the diffraction limit of the Dunn Solar Telescope) to lower resolution (0.25 arcsec/pixel) with a larger field-of-view. The DLSP is a fixed, facility-class instrument located on Port 2 and integrated with the high-order AO system and new CCD context imagers. A new modulation and demodulation package is included in order to make the instrument stand-alone. The DLSP achieves a spatial resolution equal to the diffraction limit of the DST. Context imagers include a $2K \times 2K$ G-band camera capable of frame selection, a $2K \times 2K$ Ca K imager and a $1K \times 1K$ slit-jaw imaging camera. Online Stokes inversion will be implemented into the DLSP data pipeline.

The DLSP was successfully operated during several engineering runs in 2004 and is now fully integrated with the high-order adaptive optics. Integration of the DLSP with the context imagers is underway while the instrument and its software are being fine-tuned. The DLSP will be fully commissioned for operations in July 2005. After commissioning, we will make the DLSP available for a “solar queue observing mode.” This mode will make more efficient use of the optimal seeing conditions at the DST. The solar queue observing mode will be defined within the observatory in close consultation with users and the ATST project and community. We plan to start implementation of this mode during FY 2005. In addition to more efficient DST operations and higher scientific productivity, we expect the experience gained at the DST to be very valuable in developing efficient operational modes 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. 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 (DST). 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. The project is currently in its conceptual design phase. Most of the effort is located at the IfA. The NSO will contribute 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 all-reflecting design of the McMath-Pierce gives it access to the entire solar spectrum that is transmitted through the Earth's atmosphere, and makes it the closest analogy to the proposed ATST telescope among the NSO facilities. Exploring the infrared regions of this spectrum is a high priority for NSO, and the wavelength range from 1,000-5,000 nm is the focus of the new NSO Array Camera program. The NAC will be a closed-cycle, cooled InSb 1024×1024 pixel camera and will obtain images, spectroscopy and polarization data in the 1,000-5,000 nm window. The NAC will replace the aging NSO NIM instrument, will have lower read noise, and 16 times more pixels. The NAC project is currently expecting to obtain first light images in 2005.

The NAC instrument will target several exciting science questions using spectroscopy and polarimetry at these 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 institutions. 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 to understand the basic physics of molecular line formation.

The NAC system is also planned to be a bridge to the Advanced Technology Solar Telescope near-infrared instrumentation. The NAC dewar is flexible with 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. The scientific discoveries that will come from the NAC observing runs during the next few years will drive near-infrared science programs at the ATST.

2.2.2 McMath-Pierce Telescope Control System (TCS)

Upgrades to the McMath-Pierce telescope control system are urgently needed to ensure that the facility remains competitive and maintainable. During FY 2005, we expect to identify the necessary funding source to carry out the upgrade in FY 2006. The TCS upgrade will take advantage of existing engineering experience within NSO, experience gained in the SOLIS project, as well as experience being gained with the commercial TCS of the upgraded East Auxiliary telescope.

2.2.3 Image Improvements at the McMath-Pierce

2.2.3.1 Seeing Improvement

Testing of the internal seeing in the McMath-Pierce telescope has shown that it is mostly due to the heating of the image-forming mirror. During FY 2005, fans that are expected to significantly reduce the internal seeing will be installed. The performance of the fans will be assessed with a high-order wavefront sensor that has been developed for the McMath-Pierce adaptive optics project (see below).

2.2.3.2 Adaptive Optics

The 37-actuator low-cost infrared adaptive optics is being used for many scientific investigations between 1 and 12 microns. During FY 2005, the system's capabilities will be enhanced such that it also works on planets and bright stars.

2.2.4 Integral Field Unit for the McMath-Pierce

Thanks to a grant from NSF Advanced Technology and Instrumentation (ATI) program, Deqing Ren (Penn State University) and Christoph Keller will develop an advanced all-reflective image slicer for AO-corrected infrared observations with the McMath-Pierce vertical spectrograph. This will allow strictly simultaneous spectroscopy and polarimetry over a two-dimensional field of view, a crucial capability for studying various phenomena in the solar atmosphere. During FY 2005, the unit will be designed and constructed. Deployment at the telescope is expected late in FY 2006.

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

1 NSO Telescope Operations

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

1.1 Flagship Facilities

1.1.1 Dunn Solar Telescope (DST)

The 76-cm Dunn Solar Telescope, located on Sacramento Peak at an altitude of 2804 m, is the premier facility for high-resolution solar physics. It is an evacuated tower telescope with a 76-cm entrance aperture. The evacuated light path eliminates internal telescope seeing. High-order adaptive optics provides diffraction-limited imaging under moderate seeing conditions. Two high-order AO systems, feeding different sets of instrumentation, were recently commissioned at the DST and are available to users. Over the past several years, NSO has pioneered solar adaptive optics and high-resolution, ground-based solar physics as a necessary prelude to the ATST.

Past DST observations have played a key role in understanding the solar photosphere and chromosphere and have provided fundamental knowledge about convective processes at the solar surface, small-scale magnetic fields, and the excitations of solar p -mode oscillations. More recently, high-resolution spectral and polarimetric observations with the DST have provided evidence of magnetic reconnections, the nature of flows in sunspot penumbra, twisting motions prior to solar activity, and oscillatory magnetoconvection. Recent observations of a solar active region that combined high-order adaptive optics and the diffraction-limited spectro-polarimeter have revealed fine super structure in flares and sunspot magnetic fields at the diffraction limit of the DST. This combination of AO and DLSP will open up new horizons in attempts to understand magnetoconvection and its consequences in the solar atmosphere and will provide strong scientific impetus for the ATST.

NSO will vigorously pursue the opportunity presented by high-resolution, diffraction-limited imaging at the DST with a goal of refining ATST science objectives and requirements, and ensuring growth of the expertise needed to fully exploit ATST capabilities. With the advent of AO, the DST has seen a large increase in proposal pressure and the over-subscription rate, which is nearing 100%. Major science topics that the DST is ideally suited to pursue include:

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

To support this science, the DST houses the wealth of instruments (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 μ 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 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 Section 2.3, soon will be implemented at the McMath-Pierce. 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- μ m imager and polarimeter;
- 0.3-to-12- μ m grating spectrograph;
- 0.3-to-20- μ m Fourier Transform Spectrometer (FTS);
- 6-to-15- μ m imager (NASA);
- 12- μ m 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, during FY 2005 and 2006, a new advanced image slicer will be developed in an NSF/ATI-funded collaboration between Penn State University and the NSO. The advanced image slicer will provide simultaneous 2-D spectroscopy of AO-corrected fields in the infrared within two years.

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.

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

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

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.

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. The major SOLIS instrument, the Vector Spectromagnetograph (VSM), started observations in the summer of 2003 using interim cameras. The Integrated Sunlight Spectrometer (ISS) is undergoing final installation and testing as of this writing. The final SOLIS instrument, a Full-Disk Patrol (FDP) is still being assembled in Tucson. The VSM and ISS were installed on the top of the old Kitt Peak Vacuum Telescope (renamed the Kitt Peak SOLIS Tower (KPST)) during 2004. Some data products are now available via the Internet and are being used by the research community.

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. The line-of-sight component of the magnetic field is measured with unprecedented sensitivity so that the entire disk of the Sun shows fields above the noise level. Among various uses, the daily observations are combined to provide estimates of the magnetic flux distribution over the entire solar surface. Researchers at the Naval Research Laboratory used these data to extrapolate the coronal magnetic field. They found excellent agreement between these extrapolations and the structure of the heliospheric current sheet as manifest in satellite coronagraph observations—a major feature of the heliosphere.

A major bottleneck in the recording and prompt processing of SOLIS data was removed when a Storage Area Network data system became operational. Significant effort is being expended to develop and streamline a data reduction pipeline for standard data products, some of which are already available on the Internet. However, the high quality of the data has revealed that some algorithms used previously are no longer adequate. For example, measurements of the chromospheric magnetic field cannot be done as previously because the spectrum line sometimes shows emission components in localized regions that foil simple data reduction methods. A new, more robust algorithm was developed. It also allows the

photospheric field to be determined from measurements in the wing of the chromospheric line at the same time as the chromospheric measurements. The new algorithm shows that near the disk center, the line-of-sight component of the magnetic field is typically stronger in the photosphere, but about halfway to the limb, the chromospheric field becomes stronger. This is consistent with field lines spreading out rapidly with increasing height.

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. Accordingly, two proposals for non-NSF funding to help operate and do science with SOLIS were prepared and submitted. Both were accepted, but one was for a terminal period of one-year, as that agency is ceasing support of solar research. The other proposal was funded early in FY 2005 and has allowed us to hire a post-doctoral fellow to exploit the new full-disk vector magnetograms produced by the VSM. The same proposal will fund a SOLIS observer to get better time coverage.

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.

1.1.4 Global Oscillation Network Group (GONG)

The Global Oscillation Network Group 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 provides essentially continuous observations of the solar surface velocities, ensuring that at least two sites can see the Sun at all times. This overlap minimizes data lost to bad weather or technical problems, and at the 90% coverage level the few remaining gaps can reliably be filled in to produce an essentially continuous data set. GONG's 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 data from all six sites are calibrated and merged to obtain normal mode frequencies for studying global internal structure, velocity images of small tracked portions of the solar surface for "local helioseismic probing," continuous magnetic field maps, and other science products that are made available to the community.

In addition to 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. GONG now collects 32 times more data than it did in its initial configuration, and a high-performance data handling system and data processing pipeline system is now operational. New scientific analysis modules are being developed and new data products are being made available.

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. With GONG's increased spatial resolution, we are also able to carry out local helioseismology to study small-scale three-dimensional features below the Sun's surface.

NSO will operate the 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)

The Evans Solar Facility houses a 40-cm coronagraph as well as a 30-cm coelostat. Although the Evans coronagraph is the most thoroughly instrumented in the world, the decline in staffing levels resulting from years of level funding has left NSO unable to adequately support its operation. Currently the US Air Force provides most of the operating 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 Spectrograph 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 (HAO) is planning to use the facility for some experiments in coronal magnetometry.

1.2.2 Hilltop Solar Facility

The Hilltop facility houses the white-light and H-alpha flare patrols, the coronal one-shot coronagraph, and a multi-band solar photometer. Most of the Hilltop synoptic capabilities have been or will soon be replaced by the Improved Solar Observing Optical Network (ISOON) and SOLIS. Currently, NSO only uses the Hilltop live H-alpha images to detect solar activity and 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. HAO has modified the coronal one-shot and is using this instrument to demonstrate coronal vector magnetic field measurements.

1.2.3 Kitt Peak SOLIS Tower (KPST)

The SOLIS Vector Spectromagnetograph has replaced the daily magnetograms produced by the Kitt Peak Vacuum Telescope (KPVT) and the KPVT was decommissioned in September 2003. SOLIS is now housed inside the clamshell atop the KPVT tower, which is now re-named the Kitt Peak SOLIS Tower (KPST). In addition to the VSM, the Integrated Sunlight Spectrometer is located in its thermally controlled room within the KPST. The ISS is expected to become fully operational by February 2005. The Full-Disk Patrol camera, the last of the suite of SOLIS instruments, remains to be completed and installed at the KPST during FY 2005.

The VSM is currently conducting a limited observing program that is constrained by progress in the development of the data handling system and the amount of available observing support. Currently, the VSM obtains a full-disk, longitudinal magnetogram; a chromospheric magnetogram ($\lambda 8542$) and a $\lambda 10830$ magnetogram. Occasionally, a full-disk vector magnetogram is acquired. The data are “stockpiled” on a disk system. The VSM observing day is constrained to about four hours per day (seven days per week) due to limited observing support that includes three observers (two supported by NSO and one supported by NASA). A new NASA grant from the LWS program (PI: J. Harvey) will support an additional observer with a concomitant increase in VSM observing hours. The NSO is proud to note that the impressive data quality of the VSM sets a new standard for moderate resolution magnetography.

During FY 2005, there are plans to replace several degraded VSM components including the spectrograph slit, the polarization calibration package, and the grating mount in order to correct a grating drift problem. The data handling system will be completed along with the ISS and the FDP. In addition, we will explore opportunities to augment the current observing support and thereby increase the length of the observing days. In-house science with VSM data will increase with the forthcoming addition of a postdoc supported by a NASA LWS grant (PI: J. Harvey). A potential VSM camera upgrade has been recently identified and is under investigation. The possibility of building a modulator for acquisition of chromospheric magnetic field data is being examined. Finally, promising discussions are occurring with potential partners concerning opportunities for a network extension of the VSM.

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, nearly 2.5 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 12 Terabytes of disk space, and will eventually be equipped with 18-24 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 will initially comprise a unified gateway to distributed solar data archives with access through the WWW. The system has already been accessed over 1,000 times as a beta version since December 2003, and Version 1.0 will be released in December 2004. The VSO currently provides access to more than 40 major solar data sets. 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 2005

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

INSTRUMENT	TELESCOPE	COMMENTS/DESCRIPTION
<i>NSO/Sacramento Peak – OPTICAL IMAGING & SPECTROSCOPY</i>		
Low-Order Adaptive Optics	DST	20-mode correction
Advanced Stokes Polarimeter (ASP)	DST	Photospheric/chromospheric vector polarimetry, visible,
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
UBF-Fabry Perot	DST	Tunable narrow-band filter, $R \leq 250,000$,
Horizontal Spectrograph	DST	$R \leq 500,000$, 300 nm - 2.5 μm
Echelle Spectrograph	DST	$R \leq 2,000,000$, 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/ESF/HT	380 - 1083 nm, Formats: 256 × 256 to 2K × 2K
Correlation Tracker	DST	Tip/tilt correction
40-cm Coronagraph	ESF	300 nm - 2.5 μm
Full-Limb Coronagraph	HT	Emission-line coronagraph
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å
Flare Patrol	HT	Hα and white-light full-disk images, 1 min. cadence
<i>NSO/Sacramento Peak – IR IMAGING & SPECTROSCOPY</i>		
Horizontal Spectrograph	DST	High-resolution 1 - 2.5 μm spectroscopy/polarimetry,
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 μm spectroscopy/polarimetry
<i>NSO/Kitt Peak – IR IMAGING & SPECTROSCOPY</i>		
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, $R \leq 600,000$
Near-IR Magnetograph	McMP	Vector magnetograph, 1 - 2.5 μm, $R \approx 180,000$
IR Imager	McMP	1 - 5 μm, 256 × 256, 12 Hz, imaging spectroscopy, polarimetry
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
<i>NSO/GONG – GLOBAL, SIX-SITE, HELIOSEISMOLOGY NETWORK</i>		
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 SCIENTIFIC STAFF

The primary roles of the NSO scientific staff are to carry out a balanced and forefront program of scientific research, innovative instrument development, and observing support for the solar community. In addition to these primary roles, the NSO staff also participate in educational and public outreach activities through contributions at all levels, extending from preschool and K-12 through graduate and postdoctoral education. Through successful achievement in these multiple roles, the scientific staff are able to assume both a leadership role and a critical support role, in response to the needs and priorities of the community. In order to effectively carry out these roles, the responsibilities of a scientific staff member are divided between observatory service and scientific research. AURA policy establishes a goal of allocating 50% of an individual's time for the conduct of scientific research. Experience clearly confirms the AURA management view that maintaining a strong NSO scientific staff, with active research interests, is required in order to provide US solar physicists with the best solar facilities in the world.

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

1 The Solar Exterior: The Photosphere, Chromosphere and Corona

A popular method for tracking small-scale features is narrow-band imaging in the G-band with typical pass bands of 1-nm FWHM. This technique is optimal in combination with image improving techniques like adaptive optics and post facto image reconstruction. A drawback of G-band imaging is that it does not provide measurement of the magnetic flux, which has to be obtained from simultaneous and co-spatial magnetograms in magnetically sensitive atomic lines. It would be preferable if magnetic flux could be measured in precisely those spectral lines that make up the G-band. Most of the opacity in the G-band is due to electronic transitions in the A-X band of the CH molecule with added contributions from atomic lines of different elements. The CH molecular lines are susceptible to the Zeeman effect in the presence of an external magnetic field and may produce polarized radiation that can be analyzed to infer the properties of the field. When the resulting polarization is calculated in realistic one- and two-dimensional models of the solar atmosphere with realistic field strengths, the detection of magnetic fields through analysis of the Zeeman effect in CH lines indeed seems to be possible. Together with K.S. Balasubramaniam (Bala) at NSO, H. Uitenbroek has obtained spectra of Stokes I and V in the G band. These spectra clearly show the presence of the Zeeman effect in the CH lines, confirming the theoretical calculations. Further observations with an improved instrumental setup are planned for FY 2005.

In the coming year, Uitenbroek plans to continue the development of his multi-dimensional numerical 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. Together with Bala at NSO, Uitenbroek will attempt further observations of the polarization in the G-band due to CH lines.

In addition to his G-band work, Uitenbroek will use his code to investigate the viability of the calcium infrared triplet lines for chromospheric magnetic field measurements. There is a great need for techniques that can provide measurements of magnetic field strength in the solar chromosphere. Only a

handful of spectral lines are sensitive to the field in these poorly understood layers of the solar atmosphere. Among the possible spectral diagnostics are the Ca II infrared triplet lines, the sodium D lines and the hydrogen H 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. His model calculations will complement the recently completed effort by J. Harvey in the development of a data reduction code for use with SOLIS VSM data for the inference of chromospheric longitudinal magnetic field parameters from the Ca II infrared triplet feature at 854.2 nm. Finally, Uitenbroek will use his radiative transfer code to investigate the linear polarization properties of the Na I D lines due to scattering.

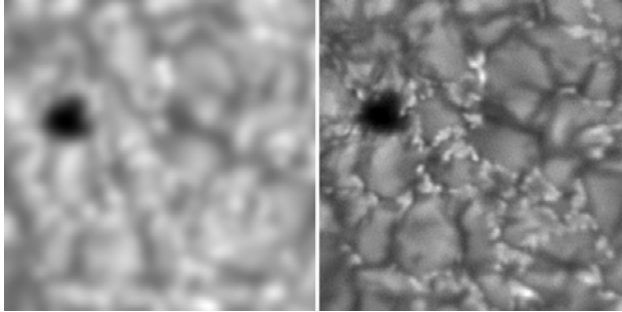


Figure IV-1. Images taken in the G-band at the NSO Dunn Solar Telescope. The image on the left is uncorrected (i.e., without AO). The image on the right was obtained with the AO system at the DST. Note that bright points are clearly observed in the intergranular lanes in the AO-corrected G-band image.

In parallel with the above observational and theoretical programs involving the utilization of the G band as a diagnostic of the dynamics of the solar photosphere, T. Rimmele published (ApJ) the analysis of diffraction-limited observations of G-band bright points. The goal of this program is to delineate the basic physics of magnetic flux tubes. By exploiting the AO systems at the Dunn Solar Telescope, Rimmele published a paper on plasma flows observed in magnetic flux concentrations and sunspot fine-structure. 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 October 24th that was part of the region producing the X17.2 flare on October 28th. A movie of the eruption of the loop system shows the footpoints of the loops, as well as some loop tops, becoming bright during the flare. The movie revealed, for the first time, flare structure at scales of 0.2 arcsec, corresponding to about 145 km on the solar surface. Rimmele plans to publish the results of the diffraction-limited sunspot and flare observations during FY 2005. In addition, he will continue his efforts toward obtaining observations at the highest spatial resolution using adaptive optics in order to study the properties and the dynamics of small-scale magnetic elements. A specific project that Rimmele is pursuing in the general area of chromospheric heating, in collaboration with Martin Woodard (Colorado Research Associates), involves characterizing the physics of chromospheric K2V bright points and their relation to acoustic waves generated in intergranular lanes.

The power of diffraction-limited observations at the DST for the study of the ubiquitous, small-scale magnetic flux on the Sun will be enhanced with the development of the diffraction-limited spectropolarimeter, a collaborative project between NSO and HAO. Sankarasubramanian Kasiviswanathan (Sankar) serves as the PI for NSO with Bruce Lites as the PI for HAO. Sankar has developed a new modulator for the DLSP. The DLSP is expected to achieve the DST's diffraction limited spatial resolution in vector magnetic field measurements (about 0.18 arcsec in the visible). Sankar is developing a technique to accurately measure the line-of-sight magnetic fields of active regions as well as a novel method to observe line-of-sight magnetograms over a range of visible wavelengths without the influence of the telescope polarization. Finally, Sankar will pursue the development of a new concept for a tunable

Stokes polarimetry. In brief summary, using the DLSP combined with a high-order AO system, observations will be carried out to attain the highest possible spatial resolutions in vector magnetic field measurements that can be achieved at the DST.

In parallel with the efforts at the DST, M. Penn has been leading the utilization of the McMath-Pierce telescope for frontier investigations in the near infrared. His analysis of spectropolarimetric observations of sunspots at 1565 nm has yielded intriguing 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, covering a large time span, 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 University, and has been submitted for publication.

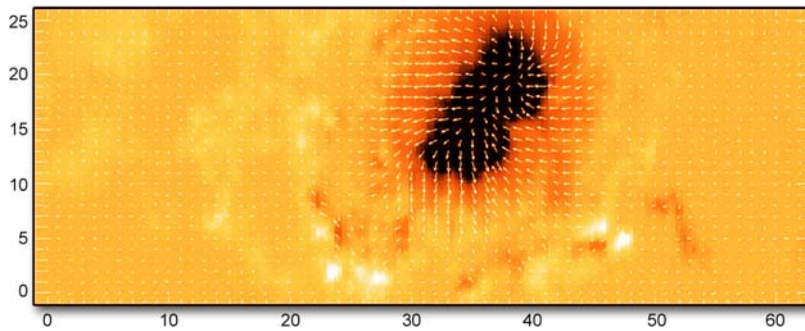


Figure IV-2. A vector magnetic field map of a sun-spot umbra and its surrounding region using near-IR observations of the magnetically sensitive 1565-nm line as obtained by M. Penn at the NSO McMath-Pierce Solar Telescope.

Penn plans to expand his efforts in vector magnetic field observations at the McMath-Pierce telescope using the 1565-nm infrared lines. 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 performed in order to characterize the plasma conditions in sunspots. In addition, Penn plans to explore in the near future polarimetry of spectral lines in the 3-5-micron wavelength range. M. Penn is leading the NSO Array Camera (NAC) project. This new IR array camera is expected to yield ultra-high precision polarimetry at diffraction-limited spatial resolutions in the infrared at the McMath-Pierce telescope. The NAC components are currently being integrated at Mauna Kea Infrared (MKIR) in Hilo, HI, and will likely be shipped to Tucson in early 2005.

During FY 2005, K. S. Balasubramaniam (Bala) will be conducting research in the areas of chromospheric dynamics, magnetic field structure in the vicinity of sunspots, sunspot hydrodynamics, and wave heating of the solar atmosphere. In the area of instrument development, Bala is working on the design of a narrow-band imaging filter for the ATST. More specifically, working in collaboration with M. Eydenberg (New Mexico Tech) and H. Uitenbroek, Bala is establishing the Principal Component Analysis (PCA) inversion schemes for non-LTE atmospheres, particularly applying them to chromospheric spectra, such as H-alpha. He also 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. This research will be in collaboration with H. Socas-Navarro (HAO).

In the area of magnetic structure near sunspots, Bala plans to obtain a series of high-resolution spectroscopic and spectropolarimetric measurements (ASP) to understand the structure of twisted flux tubes at the periphery of a sunspot, seeking evidence for reconnection. He intends to detect the twists in magnetic fields through the trail of Doppler evidence it leaves at various levels of the atmosphere, as it propagates upward of the photosphere. Using high-resolution imaging spectroscopy measurements with

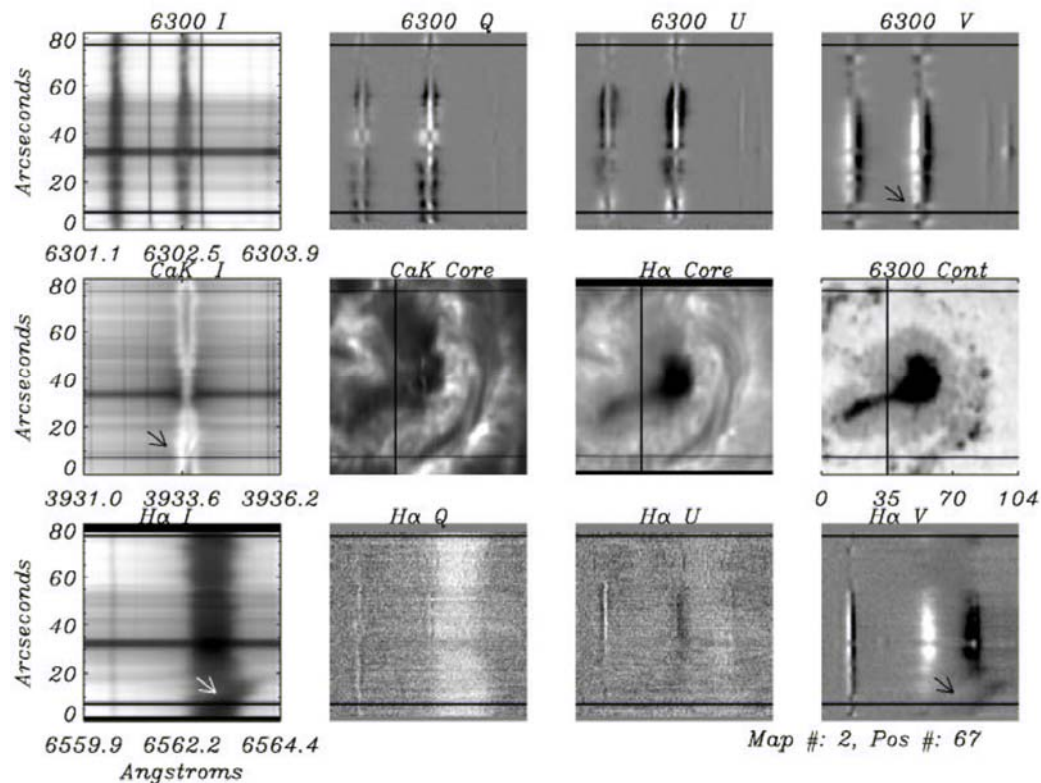


Figure IV-3. Chromospheric red-shift spur and reconnection in filaments. Active region filaments form at the periphery of sunspots. Filament foot-points connect regions of opposite magnetic polarity. The middle right columns show spectral images at the bottom of the atmosphere (continuum), chromosphere (core H α) and upper chromosphere (core of the Ca II K line). The top row shows the Stokes I, Q, U, and V polarimetric spectra about the slit for the 6300 Å region, depicted by the vertical line in the image panels. The bottom row shows Stokes I, Q, U, and V polarimetric spectra about the slit for the H α line. The left-most image in the middle row shows the corresponding Ca II K line spectra. The arrows point to locations where reconnection occurs. Notice the fork-like appearance of the K-line core, as pointed out by the arrow. The H α line and the Ca II K line show strong red-shifts, demonstrating the chromospheric red-shift spur effect. The photospheric Stokes V shows magnetic reversals at this location where reconnection occurs. From work by K. Balasubramaniam et al.

the UBF, Bala and S. Keil plan to seek signatures of rapidly moving magnetic elements that lead to reconnection at both the photospheric and chromospheric levels.

Working with A. Pevtsov and S. Olmnschenk (U. Chicago, REU), Bala is seeking to measure the sustenance and changes in the Evershed flow across sunspots using high resolution spectroscopic data. Preliminary 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. They will discuss the implications of these results for sunspot models.

The long-standing problem of the origin of the solar chromosphere is clearly related to wave heating associated with magnetic fields. Bala, S. L. Keil and C. Watts (New Mexico Tech) will embark on a project to understand the magnetic structure and dynamics of photospheric and chromospheric plage regions in an effort to understand the sustained heating structure of these regions. They will seek to verify theoretical results that the heating is due to Alfvén waves. Preliminary exploratory work with a

student, A. Medlin (New Mexico Tech), shows promising results on the search for propagating and sustained waves in transverse magnetic elements, using the ASP data.

Finally, in the area of innovative instrument development, Bala is working with G. A. Gary (NASA/MSFC) and B. Robinson (U. of Alabama, Huntsville; ATST Fellow) to develop the advanced design and configuration for the triple-Etalon filter to be used for ATST as an imaging narrow band filter.

A key milestone in the restructuring of the NSO program was reached during FY 2004 with the deployment of the SOLIS Vector Spectromagnetograph on Kitt Peak at the former site of the Kitt Peak Vacuum Telescope. The VSM is already producing full-disk magnetograms of unprecedented sensitivity. NSO Scientist C. Henney has assumed the role of program scientist for the SOLIS project where he continues to develop and maintain the data reduction procedures for the production of SOLIS-VSM 630- and 854-nm longitudinal magnetic field data products. Henney 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 continued to maintain and modify the synoptic data pipeline, previously designed for KPVT data, to produce VSM synoptic products as part of the SOLIS data handling system. In FY 2005, the primary research tasks for Henney include the calibration of the VSM instrument, vector analysis, and cross-calibration of synoptic products with the KPVT and other instruments. In addition, Henney will continue to calibrate various solar activity forecasting parameters derived from new VSM data products.

SOLIS Project Scientist J. Harvey supports Henney in his efforts. During FY 2004, Harvey concentrated on SOLIS, correcting known errors in the archive of Vacuum Telescope data, instrumental issues associated with the upgrade of GONG, and preparing proposals for the support of SOLIS operations. During FY 2005, J. Harvey will continue to concentrate on completion of the SOLIS project and GONG instrument improvements. C. Keller is the telescope scientist for the SOLIS VSM. During FY 2005, Keller will concentrate on producing the first science results from the vector magnetic field data collected by the SOLIS VSM. He then expects to leave NSO for a new position at Utrecht University in July 2005.

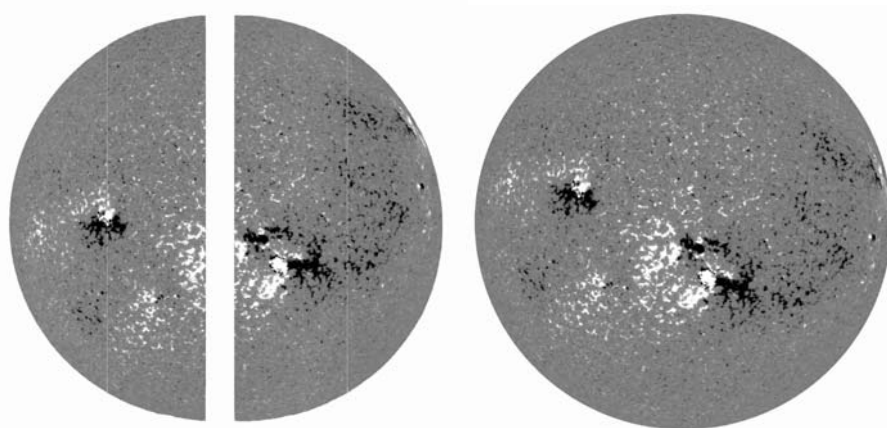


Figure IV-4. An example of a SOLIS-VSM 630.2-nm longitudinal magnetic field image before (left) and after (right) combining the two camera frames, correcting for atmospheric refraction and the slit curvature, removing the observed p -angle, and correcting the spatial magnetic bias signal.

Overlying the solar chromosphere and photosphere is the tenuous, ~ 2 million-degree plasma of the solar corona. The corona is the site of the most energetic, explosive events in the solar system. The origin of this hot region—in apparent violation of the laws of thermodynamics—remains enigmatic while its observation presents a rich array of structure. Among these structures are X-ray and EUV bright points. A. Pevtsov and his colleagues developed an automated procedure to identify X-ray and EUV bright points (BPs). This procedure was applied to SOHO/EIT data to study various properties of bright points near the minimum of solar activity. It was found that the distribution of BPs exhibits large-scale structures that might be related to magnetic areas with different degrees of flux imbalance. The latitudinal distribution of BPs shows an enhancement at active region latitudes. The total number of BPs did not change between 1996 and 1997, but it increased by about 20% in 1998.

To understand the role of large-scale reconnection in heating the solar corona, Pevtsov and one of his summer students studied the evolution of magnetic flux and the associated X-ray brightness of the quiet solar corona in the vicinity of an emerging active region. They found that as an active region emerges, the corona increases its brightness at a large distance from emerging flux. Pevtsov and his student-collaborators observed increases in temperature but no significant changes in the magnetic flux properties on the quiet Sun around the emerging region. They interpreted their findings as coronal heating associated with magnetic reconnection between the new and pre-existing flux systems.

In FY 2005, A. Pevtsov will continue to study the properties of X-ray and EUV bright points and associated photospheric bipoles; the role of magnetic fields in coronal heating; and the relationship between solar drivers and geomagnetic storms. Other research plans include the study of helicity of rotating sunspots, the evolution of delta-spots, plasma flows in and around emerging active regions, and the origin of periodic structures in quiescent prominences.

2 The Sun as a Star

M. Giampapa will continue his study of the magnetic activity in the solar-type stars in the solar-age and solar-metallicity open cluster M67. However, he will now pursue this project within the context of the recently approved, joint University of Arizona/NOAO NASA Astrobiology program. Giampapa is a Co-Investigator in this program where his efforts will 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 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. During FY 2004, Giampapa hired a postdoc, William Sherry (PhD, Stony Brook), under the auspices of the Astrobiology program to collaborate in this effort.

M. Giampapa and V. Andretta (U. Naples) will continue their analysis of a unique data set of simultaneous He I spectroscopic observations of solar-type stars at 587.6 nm and 1083 nm, respectively. They have developed a technique to estimate fractional active region area coverage on Sun-like stars based on these high-excitation, chromospheric diagnostics. Active region area coverage is considered a key property of the underlying dynamo process.

Both S. Keil and M. Giampapa will begin to utilize the SOLIS Integrated Sunlight Spectrometer to analyze high resolution synoptic spectra of the Sun-as-a-star in key chromospheric and photospheric diagnostics, such as the Ca II H and K resonance lines. Keil is especially interested in through measure-

ments 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.

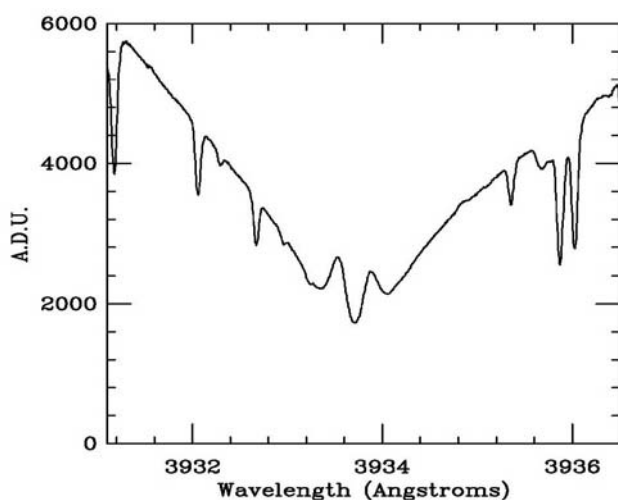


Figure IV-5. The Ca II K line in the Sun-as-a-star, as recorded by the Integrated Sunlight Spectrometer (ISS) of the new NSO SOLIS facility. The resolving power is $R = 300,000$ and the approximate central wavelength of the feature is 3933.66 \AA . The chromospheric K_2 emission peaks and the central K_3 feature formed in non-LTE are clearly visible. The ISS utilizes an 8-mm diameter fiber to scramble the incident sunlight so that the Sun appears as a star at the entrance slit to the bench spectrograph.

3 Laboratory Spectroscopy at the NSO

The NSO is the site of the Fourier Transform Spectrometer, located at the McMath-Pierce Solar Telescope Facility. This unique instrument provides broad spectral coverage with extremely high precision in wavelength stability for solar observations and applications in laboratory and upper atmospheric spectroscopy. In particular, the FTS achieves high resolution (0.0025 cm^{-1} at 1000 cm^{-1} and 0.01 cm^{-1} at 3000 cm^{-1}), excellent signal-to-noise ratio (500:1 for a 3600 sec integration) and wide bandpass (1000 – 3000 cm^{-1} for a single spectrum). This means that high quality measurements of line positions, line strengths and line widths can be readily obtained.

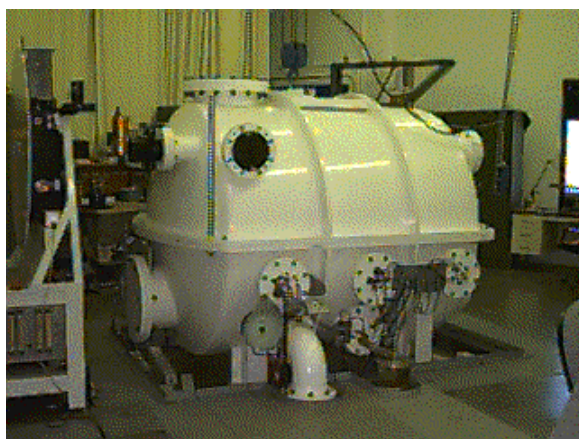


Figure IV-6. The McMath-Pierce 1-meter Fourier Transform Spectrometer (FTS) is a folded Michelson interferometer housed in a vacuum vessel. The instrument is available for use either in conjunction with the McMath's main beam or with laboratory sources. It should be considered when very accurate line positions are needed, when broad spectral coverage is required, when a stable instrumental profile is desirable, or when working in the infrared.

M. Dulick serves as the NSO FTS Instrument Scientist for visiting investigators funded under the NSF Chemistry grant for Laboratory Fourier Transform Spectroscopy, with specific duties that include providing assistance in the experimental design and setup, and the instructional use of the instrument. Dulick's research plans for FY 2005 include continued use of the McMath FTS to record laboratory spectra of diatomics in the infrared and visible to aid in the assignment of sunspot spectra. A significant

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

4 The Solar Interior: Helioseismology

Recent work by F. Hill, 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 three-year unbroken span of Carrington maps of the flows in the outer solar convection zone. A preliminary result is the apparent correlation between kinetic helicity below the surface and the level of flaring activity in an active region on the surface. In addition, the large flare of October 29, 2003 showed an anomalous helicity signal prior to the flare, which vanished after the event. These results point to a physical model of flares resulting from sub-surface “tornadoes,” and could lead to a solar activity predictor. In the context of GONG observations of flare activity, J. Harvey and J. Sudol found that all of 15 large solar flares observed with GONG longitudinal magnetic field measurements showed abrupt, large and permanent changes in the photospheric magnetic field under the flares. This particular work is being prepared by Harvey and Sudol for publication in FY 2005.

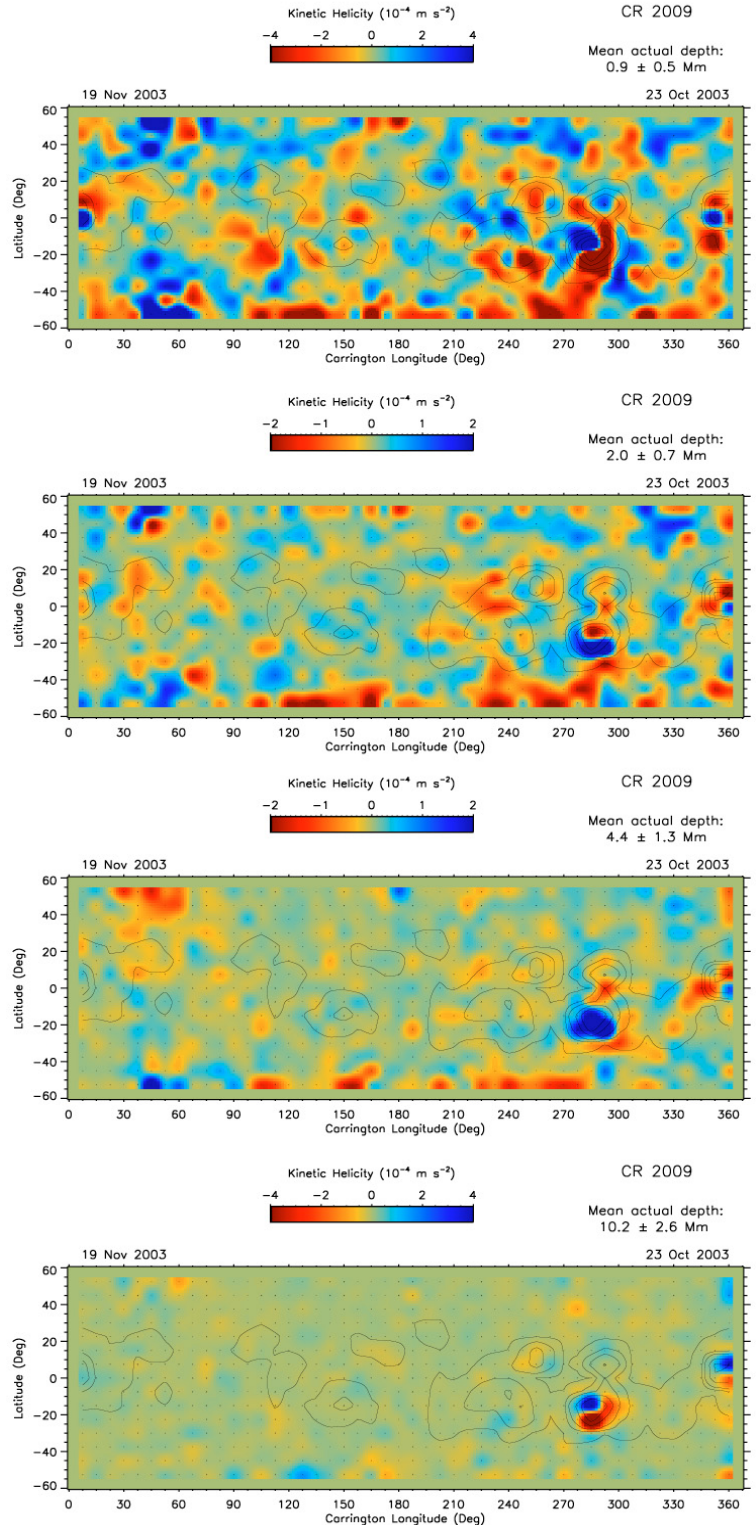


Figure IV-7 (right). Maps of the mean kinetic helicity density (KHD) as a function of depth for Carrington Rotation 2009. The KHD, defined as $\mathbf{v} \cdot \nabla \times \mathbf{v}$, is a measure of the “twistedness” of the flows below the surface. Each panel is at a different depth (0.9, 2.0, 4.4, 10.2 Mm from top to bottom). The contour lines indicate the mean surface magnetic flux. The strong KHD signal at Carrington longitude 280° and latitude -20° is located at the site of the extremely strong flares of late October 2003. The maps were obtained from ring-diagram analyses of GONG data.

In a parallel effort, R. Komm 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). He is also studying the relation between solar oscillations, granulation, and magnetic activity (in collaboration with V. Astley, an REU summer student he mentored in 2003). More specifically, Komm will explore the dynamics of the near-surface layers and the interaction between flows and magnetic flux by deriving fluid dynamics descriptors from ring-diagram data. He will continue studies of the solar cycle variation of mode parameters of solar oscillations with the focus on the mode background amplitude and other indicators of mode physics. He will continue to study advanced time-series analysis techniques such as empirical mode decomposition and Hilbert transform (in collaboration with M. Roth, Freiburg, Germany) in order to evaluate their usefulness for helioseismology. With these techniques, Komm will continue to study the relation between solar oscillations, granulation, and magnetic activity, particularly the detailed relationship between p -mode energy and magnetic activity.

The origin of solar magnetic activity is widely considered to be associated with an interior dynamo that operates near the base of the solar convection zone. J. Leibacher is testing models of solar internal dynamics and the dynamo using new methods for measuring sub-surface meridional flows, and applying them to the entire, continuous GONG dataset. Leibacher is also pursuing ideas about the observational signature of the convective excitation of p -mode oscillations using

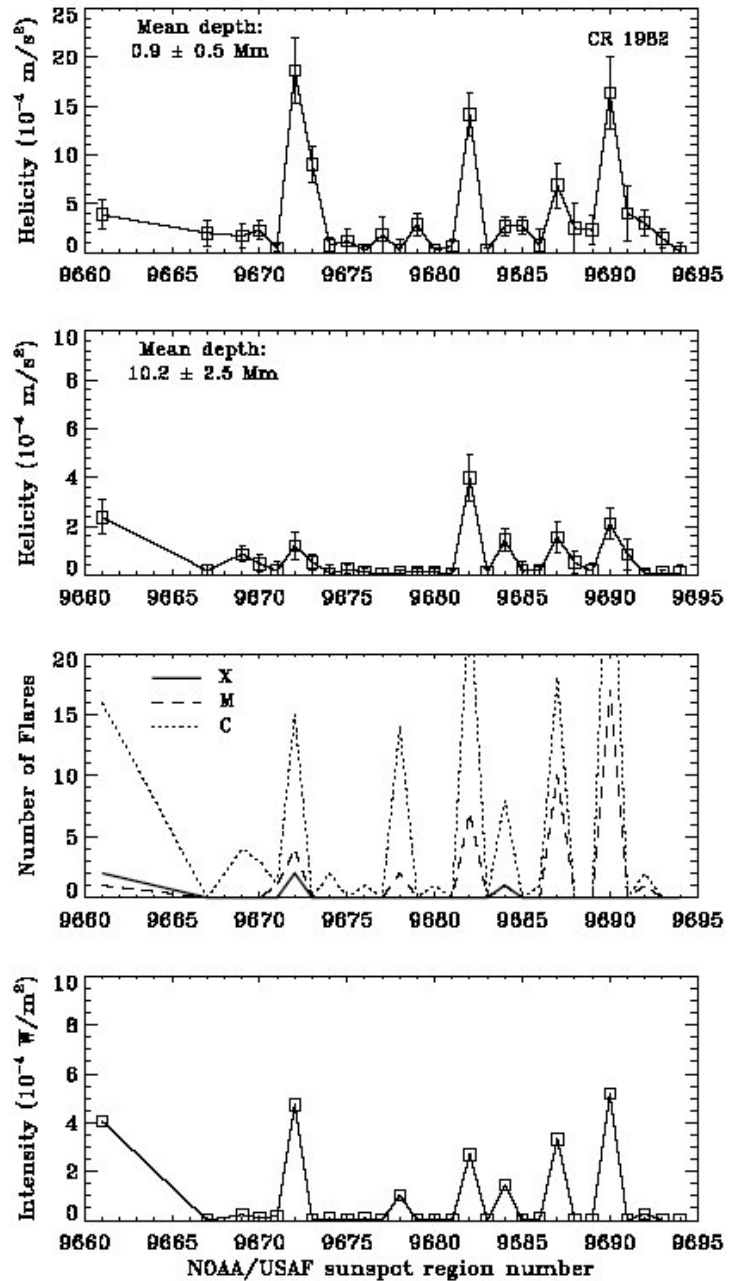


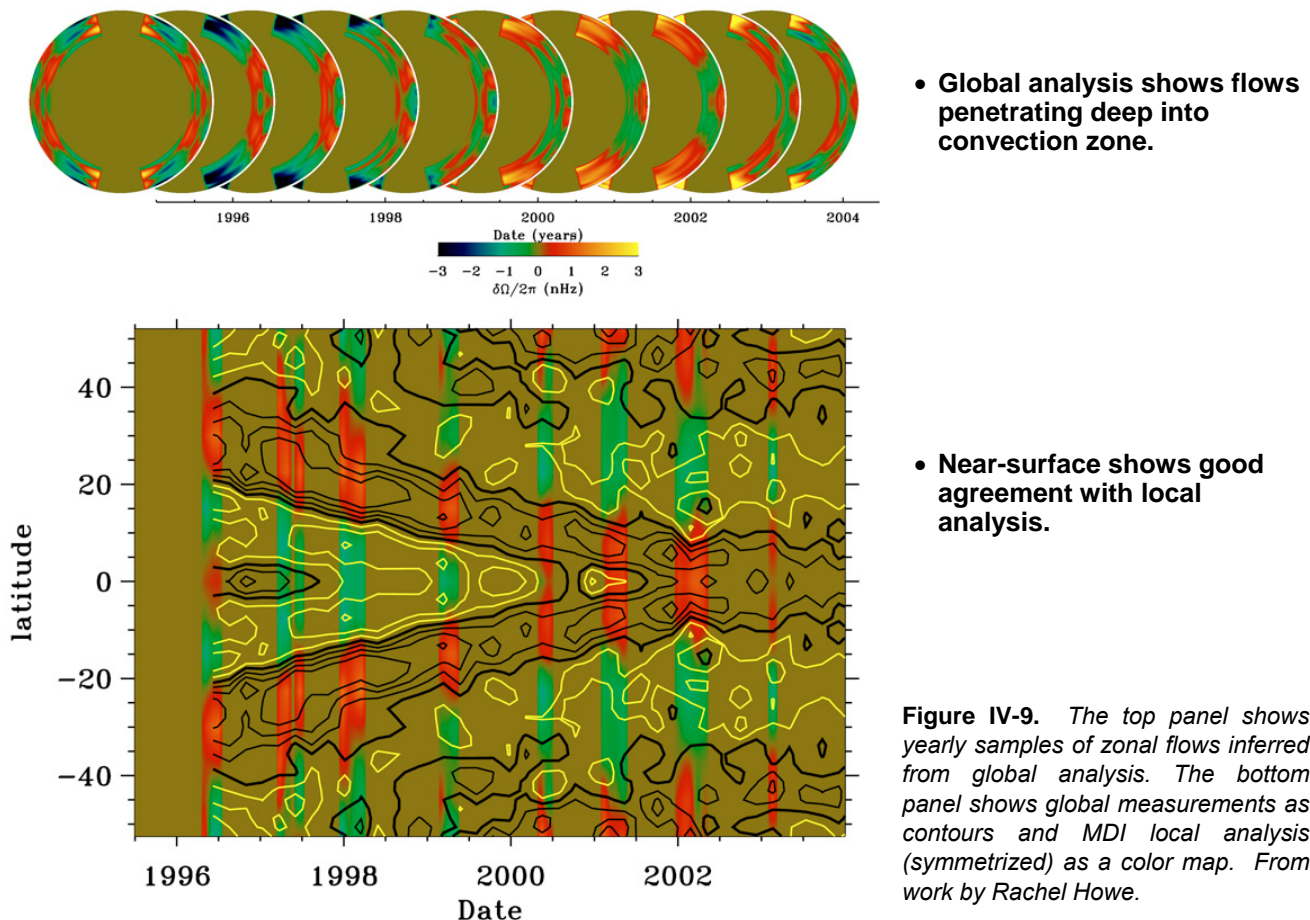
Figure IV-8. Top panel: maximum kinetic helicity density (KHD) at depth of 0.9 Mm as a function of active region number. Second from top: maximum KHD at a depth of 10.2 Mm. Third from top: number of flares by x-ray class (X, M, C). Bottom: total x-ray intensity. There is a clear correlation between subsurface KHD and flaring activity in an active region. Work performed by R. Komm, R. Howe, I. González-Hernández, F. Hill, J. Sudol, C. Toner & T. Corbard, presented at the RHESSI-SOHO-TRACE Sonoma meeting Dec. 8-11, 2004.

data from GONG as well as the SOI/MDI instrument onboard the SOHO spacecraft, in collaboration with colleagues at the Institut d'Astrophysique Spatiale (Orsay).

Hill plans to probe the lower convection zone in the region of dynamo operation 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 will also extend the spectral line modeling to include different atmospheric heights. I. González Hernández has also utilized a large-aperture ring diagrams technique to analyze two years of continuous GONG data to search for solar meridional circulation variability. The preliminary results show a marked correlation between the B_0 solar angle and the presence of a circulation countercell. She has also spent some of her time trying to modify this local helioseismology technique to probe deeper into the solar interior by using medium- ℓ spherical harmonic rings.

I. González Hernández will continue to devote part of her time to support the ring diagrams pipeline. She will analyze and search for an interpretation of the data obtained in the context of solar meridional circulation variability. Recently, I. González Hernández began working in the GONG Farside (holography) project. The objective of this project is to use GONG data for space weather forecasting. She will be proposing and developing analysis tools to check and calibrate the solar signal obtained from this technique.

ZONAL FLOWS



Earlier in 2004, R. Howe published papers with D. Haber and B. Hindman (U. Colorado), F. Hill and R. Komm on width and amplitude variations in GONG and MDI local helioseismic data. She also presented results on global and local helioseismology and flare observations with GONG at the Living with a Star workshop in Boulder, Colorado, the AAS/SPD Denver meeting, the GONG/SOHO meeting at Yale University, and the NSO Workshop on Large-Scale Structures.

Howe is collaborating with M. Rempel (HAO) on simulations of solar rotation variation, and with colleagues at the University of Birmingham, UK, on low-degree helioseismic mode fitting. A collaboration with colleagues at the University of Colorado on the variation of mode frequencies from local helioseismology is also ongoing. Howe intends to continue working on the above areas in addition to her work on the temporal variation of the solar rotation.

The maximum scientific utilization of GONG data depends critically on the ongoing refinement of reduction and analysis routines. C. Toner is currently using MDI as a fiducial “site” in order to accurately align the entire GONG Network and remove spurious “wobbling” of the merged images. He is developing an approach that utilizes regular noon drift-scans to maintain the alignment of the Network after MDI is shut down. Toner has nearly completed the automation of the drift-scan processing. Once completed, Toner plans to publish the details of the procedure in FY 2005.

5 NSO Outreach to the Community: A Brief Overview

Through the enterprise of its scientists, NSO has obtained substantial funding over the last decade for several major projects (GONG, SOLIS, AO, ATST Design and Development phase, and ISOON) that service the solar community. While these projects also involve major commitments of staff time to develop and operate, NSO scientists nevertheless remain scientifically productive as documented in the NSO annual report. To support the staff scientists’ research, while simultaneously contributing to the education of young scientists, NSO supports a number of graduate and undergraduate students each summer, and several during the academic year, to assist with observations and data analyses. NSO also holds one or two international workshops each year with topics that relate to staff research. These workshops are well attended (80-100 participants) and provide the NSO staff an additional chance to interact with other scientists in an informal and productive atmosphere.

V EDUCATION AND PUBLIC OUTREACH

NSO has a comprehensive public affairs and educational outreach plan that includes 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 V-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 V-1, NSO devotes about 5% of its resources to outreach.

Table V-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 2004 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 year include Michael Eydenberg (MS, New Mexico Tech), Klaus Hartkorn (PhD, NJIT), Jose Marino (PhD candidate, NJIT), Jose Céja (MS, University of California, Northridge), and Dave Byers (PhD, Utah State University). 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. Two new students, Andrew Medlin (MS candidate, New Mexico Tech, working on chromospheric Alfvén Waves) and Brian 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 under-graduate 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 comprised 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), both employing the Contemporary Laboratory Experiences in Astronomy software 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. NSO/Sunspot mentored a visually handicapped student sponsored by the New Mexico Commission for the Blind in the summer of 2004. We anticipate repeating this work in summer 2005 and using this as a means to enhance educational activities to serve the blind and visually handicapped.

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 has started developing a proposal for a solar system model for the Sunspot Astronomy and Visitor's Center. The model ultimately will include a 16-ft walk-through model of the Sun 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 matches the size of the Starlab planetarium dome 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: Max 2008, 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. Max 2008 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). Other Suns for Other Worlds will take the natural interest in nighttime astronomy and the hunt for other planets supporting life as a means of teaching about our Sun. Development of classroom activities for Other Suns will start in FY 2005. 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 Max 2008, Other Suns, and existing programs to schools and public events. Operating and staffing requirements for the Sun on Wheels will be defined in 2005. 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.

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 Space Sciences Department of the University of Arizona 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 anticipate completion of 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. This has been delayed by software problems but is nearing completion. NSO is exploring a new exhibit, Ride a Magnetic Carpet, to educate visitors about the magnetic nature of the Sun. 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, and as a major component of Max 2008 (above), NSO will initially 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 use 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 exhibit again at the National Science Teachers Association annual convention and will join the Association of Science and Technology Centers. NSO is applying to join the outreach component of NASA's Living With a Star 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. We will continue a series of public lectures with the Lodestar planetarium in Albuquerque. Three were delivered in FY 2004 and a fourth will be given in December 2004. Lodestar has requested two additional lectures in calendar year 2005.

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. Initial offerings will be posted in the spring 2005.

VI MANAGEMENT AND BUDGET

1 NSO Organization

Currently, NSO is managed in three major functional units, NSO/Sacramento Peak (NSO/SP), NSO/Tucson (NSO/T), and NSO/GONG, and a major project developing the ATST. 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 VI-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. 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 the solar telescopes on Kitt Peak including the new SOLIS instruments, offices in Tucson, and conducts projects at the Tucson facilities. NSO shares support personnel with KPNO on Kitt Peak and with the other NOAO divisions in Tucson. Major projects at NSO/T include final 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, collects, processes and provides data to users.

A high-level organizational chart is shown in Figure VI-1. Detailed charts are shown in Appendix G. As NSO fully establishes independent operations and begins development of the ATST, the management structure will evolve over the next few years. When the ATST is completed, NSO will completely reorganize and consolidate its resources.

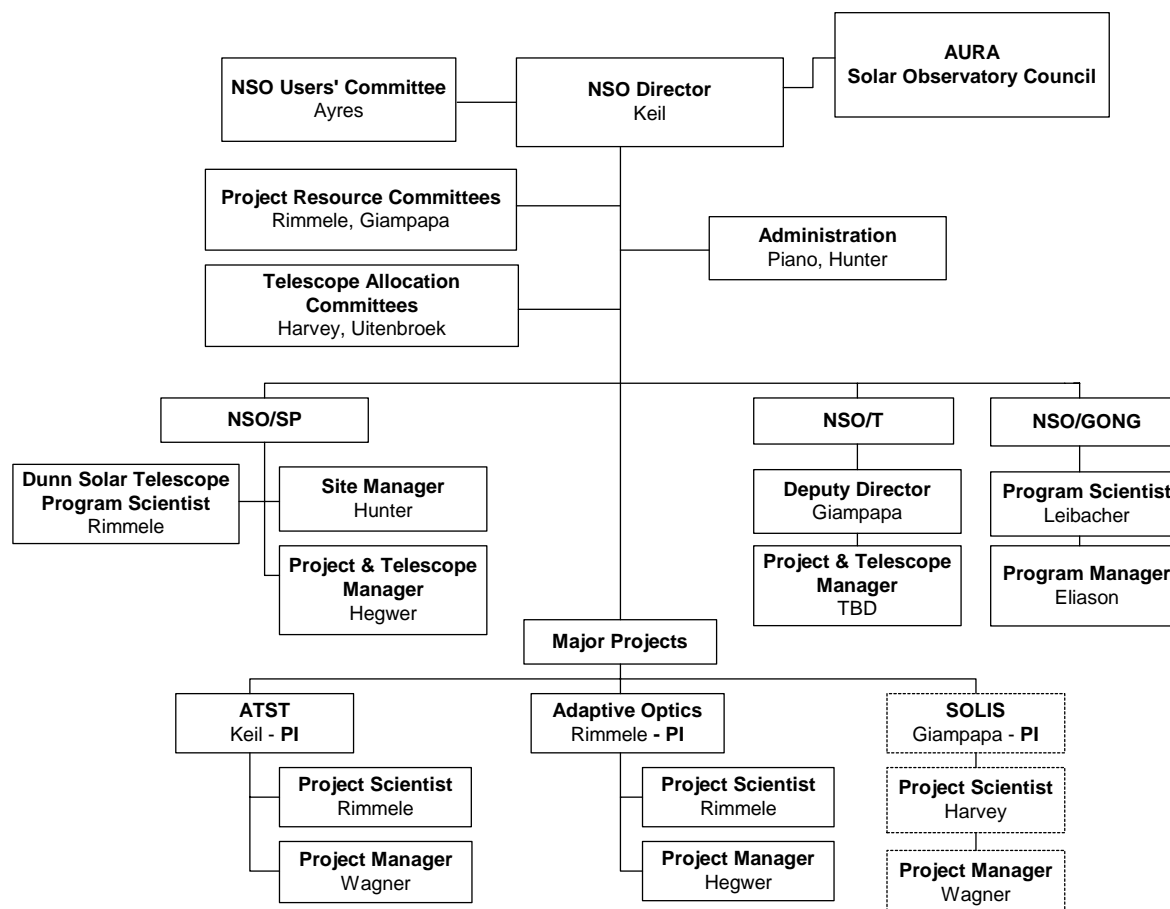


Figure VI-1. High-Level Organization Chart

2 FY 2005 Spending Plan

Table VI-2 summarizes the NSO budget in FY 2005 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 \$10,720K for its combined base program (Tables VI-4 through VI-9) and the ATST project (Table VI-10). In addition, we plan on receiving \$13K from the NSF Atmospheric Sciences Division to support the ATST. NSO also receives operational support from the Air Force Research Laboratory, under an MOU between the AF and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NASA provides a small amount of operational support for SOLIS (\$32K). 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 VI-2. NSO FY 2005 Funding	
<i>(Dollars in Thousands)</i>	
NSF Astronomical Sciences Division Funding	\$10,720
NSF Atmospheric Sciences Division Funding	13
AFRL Support for Sac Peak Operations	450
NASA Support for Kitt Peak Operations	32
NSF REU/RET Program	80
Revenues (Housing, Kitchen, Visitor Center)	176
Total NSO Funding	\$11,471

In addition to the funds shown in Table VI-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 VI-3 summarizes the planned spending by functional unit, and Figure VI-2 shows the percentage of the programming going to each area.

Table VI-3. NSO FY 2005 Planned Spending by Functional Area	
<i>(Dollars in Thousands)</i>	
Director's Office ¹	\$394
AURA Corporate Fee	266
Educational & Public Outreach (EPO) ²	284
Tucson/Kitt Peak	2,029
Sacramento Peak	2,429
GONG	2,732
ATST D&D Effort	2,368
ATST Increment	0
ATST In-House Contribution ³	657
SOLIS	300
Total NSO Program	\$11,471

¹ Contains \$18K of programmed indirects.

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

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

The EPO line in Table VI-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.

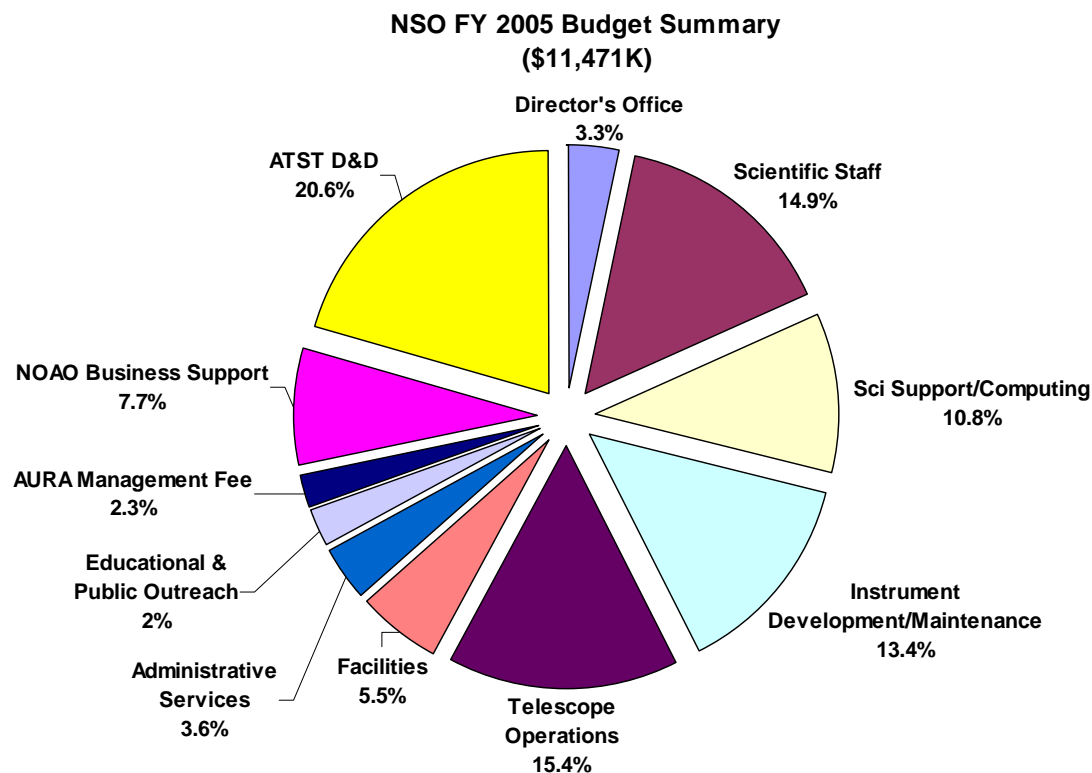


Figure VI-2

Tables VI-4 to VI-9 break out the spending plan for the major functional units in more detail. The funding summarized on the outreach line of Table VI-2 that is spent in each 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 VI-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. The plan for the \$43K reserve is to provide an NSO-wide salary adjustment to bring NSO salaries in better alignment with universities.

Table VI-4. Director's Office			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Staff	294	29	322
Committees		12	12
NOAO Support	12	5	25
Reserve		43	43
Total Director's Office	\$305	\$89	\$394
Outreach Support from NOAO	78	34	112

Table VI-5 shows the budget breakdown for Tucson operations. The \$32K received from NASA supported the operation of the KPVT and will now support SOLIS. Most of the instrument development program will be devoted to putting the ALADDIN array infrared camera online.

Table VI-5. NSO/Tucson			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	731	43	774
Scientific Support/Computing	182	10	192
Instrument Development	307	45	353
NOAO ETS & IRAF Support	105	0	105
Telescope Operations	137	71	208
NOAO Support	317	79	396
Total NSO/Tucson	\$1,780	\$251	\$2,029
Outreach (REU/RET)	32	8	40

Table VI-6 breaks out the Sacramento Peak operations budget. Instrument development is concentrating on adaptive optics 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 VI-6. NSO/Sacramento Peak			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	373	43	415
Scientific Support/Computing	168	106	274
Instrument Development	473	48	521
Telescope Operations	171	26	197
Facilities	279	351	630
Administrative Services	218	25	243
NOAO Support	119	30	149
Total NSO/Sacramento Peak	\$1,800	\$628	\$2,429
Outreach (REU/RET)	92	39	132

Table VI-6 contains the \$450K contribution of the USAF as well as the revenues earned from housing, meal services, and Visitor Center sales. The USAF funding is added to the general operations funding of the NSO to offset the support given to the Air Force Research Laboratory program at Sac Peak. Table VI-7 provides a breakdown of how these funds are used to support the AFRL program.

Table VI-7. Air Force FY 2005 Funding			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Support/Computing	55	29	84
Telescope Operations	28	5	33
Instrument Development	100	25	125
Facilities	74	76	147
Administrative Services	48	10	58
Total Air Force	\$305	\$145	\$450

Table VI-8 summarizes the GONG spending plan for FY 2005. 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).

Table VI-8. NSO/GONG			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	371	51	422
DMAC Operations	461	229	690
Telescope Operations	444	688	1132
Administrative Services	154	16	170
NOAO Support	254	63	317
Total NSO/GONG	\$1,684	\$1,048	\$2,732

SOLIS spending is shown in Table VI-9. SOLIS will also receive scientific support from within the NSO programs at Tucson and Sunspot. Part of the SOLIS operation is supported by personnel working under a NASA grant.

Table VI-9. NSO/SOLIS			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	82	0	82
Telescope Operations	86	146	232
Total NSO/SOLIS	\$168	\$146	\$313

2.1 ATST Program

Table VI-10 summarizes both the NSO in-house investment in the ATST and the ATST project funding NSO expects to receive in FY 2005. The NSO in-house contribution to the ATST includes the development of an adaptive optics design that will be scalable to the large aperture of the ATST; investment in IR camera technologies needed to use the ATST in the 1.0- to 28-micron wavelength range; support for technical trade studies for heat control, scattered light, telescope contamination issues and off-axis design; and support for the site survey operation. Additional funding for the ATST is being provided by NSF/ATM to support HAO's participation in the project. This funding is shown separately in Table VI-11. It covers the development of an instrument design for a visible light polarimeter and participation in the

design of an IR polarimeter led by the University of Hawaii. The tables do not show carry over from FY 2004 to FY 2005. ATM provided most of their FY 2005 contribution using FY 2004 year-end funds.

The design and development phase of the ATST project covers five years, beginning in the last few months of 2001 and ending in 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 2007 or perhaps later start. Thus, the ATST project is requesting additional D&D support to begin some of these final design efforts in FY 2005 and FY 2006, as well as to conduct environmental assessment of the recommended ATST site on Haleakala. The request for additional funding is explained in Section II-1.1.4.

Table VI-10. NSO/ATST			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
<i>In-House Contribution</i>			
Science Support	100	0	100
Technical Support	200	0	200
AO	236	80	316
IR	0	41	41
<i>Total In-House Contribution</i>	\$536	\$121	\$657
<i>ATST D&D Project</i>			
ATST Project Staff	1223	112	1335
Science Travel		40	40
Collaborator Awards (Design)		281	281
HAO Subcontract (ATM Funding)		13	13
Contracts		435	435
Educational Outreach	89		89
NOAO Shared Services	173		173
AURA F&A Fee @ 1.9%		46	46
<i>Total D&D Project</i>	\$1,485	\$928	\$2,413
Total ATST	\$2,021	\$1,049	\$3,070

Table VI-11. HAO ATST FY 2004 Spending Plan (NSF/ATM Funding)			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Visible Light Polarimeter	6	4	10
IR Polarimeter (with Hawaii)	2	1	3
Total HAO ATST Program	\$8	\$5	\$13

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, NOAA, etc.) will continue as long as they are fully funded.
2. Operate SOLIS by devoting NSO resources currently used to operate and reduce data from the KPVT. NASA plans to continue providing operational support and we are developing proposals to find additional support.
 3. Operate the new high-resolution version of the GONG network.

2.3 Strategic Needs

The NSO long-range plan (FY 2004-2008) 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 \$2.3M in FY 2005: 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–1.1.4. 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 Telescope. Both systems currently use very outdated computers and replacement parts and servicing is 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 2005

This section describes the major project milestones for 2005.

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 integrating the selected site into our planning, preparing for and establishing vendor design completion contracts. Specific milestones for the ATST and related instrumentation programs include the following:

- 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.

A2. Solar Adaptive Optics

- Conduct additional MCAO observing runs at the Dunn Solar Telescope.
- Conduct detailed performance evaluation.
- Complete the documentation for AO systems.

A3. Diffraction-Limited Spectro-Polarimeter

- Test and fine-tune the instrument and its associated software.
- Integrate the DLSP camera with other instrument control computer (ICC) cameras.
- Conduct a few scientific runs with the instrument.
- Release the DLSP as a user instrument in 2005.

A4. 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.

A5. 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.
- Start routine operation of the automatic image quality assessment software.
- Continue to develop local helioseismology methods, implement routine data production, and add new products to the archive.
- Start routine operation of the near-real-time “farside” imaging pipeline.
- Implement high spherical harmonic degree global p -mode processing.
- Develop a plan to secure increased bandwidth from the sites sufficient to transfer GONG data near-real-time.
- Implement a 3-year software plan for GONG’s data processing and development.

A6. NSO Array Camera (NAC)

- Integrate and test the controller and dewar with the NSO ALADDIN array.
- Conduct initial science observations at McMP; spectroscopy.
- Develop polarimeter interface software and observing scripts.

A7. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- Integrate achromatic optics (modulator, retarder) and integrate enhanced anti-reflection (AR) coated transfer optics.
- Demonstrate half wave retarder at the polarizing beamsplitter, reduced fringe modulator, and Sarnoff cameras.
- Define communication protocols for mechanism control and for virtual cameras.

A8. IR Polarimeter

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

A9. Dunn Solar Telescope Control and Critical Hardware (Systems 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.

APPENDIX B: STATUS OF FY 2004 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2005 Program Plan. (FY 2004 milestones appear in italics below.)

B1. ATST

Submit the ATST construction proposal.

The ATST construction phase proposal was submitted at the end of calendar year 2003. The construction proposal review has proceeded successfully through the write-in review in the spring of 2004 and the face-to-face panel review in August 2004.

Complete follow-up activities from the CoDR recommendations.

The enclosure was identified as the area needing the most work during the past year. M3 Engineering was placed under contract to refine the design, costing and performance-based analysis. M3 submitted their final report in early October and participated in a major enclosure review workshop held in late October 2004.

Establish design contracts.

The project is preparing for the Systems Design Review scheduled for late March 2005. Preparations for design contracts (DRDs, ICDs, etc.) are underway and will be reviewed at that time.

Rework program plan based upon vendor feedback.

The program planning efforts include feedback from the vendors regarding cost and schedule estimates.

Complete site testing to prepare for final site selection.

The Site Survey Working Group released its final report in early October 2004. The Science Working Group met in mid October and submitted its recommendations for the primary site and alternate sites.

Continue to develop funding partnerships for the construction phase.

Letters of support have been received from European partners as well from the Air Force Research Lab.

Hold the system-level preliminary design review in October 2004.

The Systems Design Review is scheduled for the week of March 21, 2005.

B2. Solar Adaptive Optics

Complete integration of the DLSP and high-order AO and commission it as a user instrument.

The DLSP has been integrated with the high-order AO at Port 2, and the DLSP is expected to be released as a user instrument in early 2005.

Upgrade low-order AO to high-order AO.

Completed.

Conduct science runs with both high-order AO systems.

The AO systems have been commissioned as user instruments and are being used at a high percentage rate for science runs.

Complete the development of point spread function (PSF) estimation software.

The software development has been completed and verification and science applications are now in progress.

Develop multi-conjugate AO (MCAO) wavefront sensor real-time software and control.

Completed.

Conduct MCAO engineering runs at the DST.

Two engineering runs were performed and functionality of the MCAO system has been demonstrated.

B3. Diffraction-Limited Spectro-Polarimeter*Develop a user-friendly graphical user interface (GUI) for the DLSP.**Test the performance of the DLSP for the large FOV mode.**Integrate the DLSP camera with other instrument control computer (ICC) cameras*

All of the above milestones were completed in November 2004. The DLSP is expected to be released in early 2005.

B4. SOLIS*Complete construction and testing of the ISS and FDP.*

The ISS suffered from a series of camera failures that prevented completion of this task. The vendor has implemented power supply changes that appear to have fixed the problem. The ISS is located on Kitt Peak and is now in final testing. The FDP also suffered from a major camera failure. The vendor of the FDP cameras fixed the problem. The FDP is now awaiting availability of personnel to complete construction and start testing.

Complete the guider.

Prototype development is nearly finished. The guider has demonstrated good closed-loop performance with a solar image in a lab environment. A control issue arose that is being solved by construction of a digital integrator to convert velocity information into position data.

Develop an upgrade path for the VSM cameras.

This is an effort to find cameras to replace the interim cameras that had to be installed when the original vendor defaulted. The interim cameras are too slow and noisy for the VSM to reach its ultimate performance. Two interesting options have been located. One is a commercial camera (CAM1M100) from Sarnoff Corporation. The other is from a new company, Salvador Imaging, and consists of a 256 × 2048 format. This would allow us to use a single camera and a single re-imaging path after the focal plane. Both possibilities are being investigated as time permits.

Move SOLIS to Kitt Peak.

Done. The FDP will be placed on the SOLIS mount after construction and testing is finished in Tucson.

Fix initial ISS and FDP startup problems.

This is underway with the ISS. The FDP has not yet reached initial operational status.

Develop a viable SOLIS operations plan with constrained funding.

The shortfall in operational resources is being addressed by short observing days, extended development time for reduction algorithms and personnel additions funded by outside-agency soft money.

Submit a plan for developing a SOLIS network through partnerships.

Delayed until it is demonstrated that SOLIS produces data of the promised quality, viable partners are identified, and stable operation of the first unit is achieved. Discussions with Air Force Research Laboratory personnel about options for combining SOLIS and ISOON joint needs for networking are underway.

B5. GONG*Continue transformation to long-term operations, with emphasis on in-house science.*

The program continues its transition to steady-state operations following an action plan called out in a program restructuring review. One data processing position has been converted to a scientific staff position, and additional funding for science positions has been found.

Restore the engineering site to a full-function system.

Progress has been made in restoring the Tucson site to a full-function engineering system, however until the backlog of deferred maintenance is reduced, the system will continue to be used for burn-in and acceptance testing in addition to trouble-shooting, diagnostics, risk and failure analysis, and re-engineering.

Rebuild and re-engineer light-feeds, subsystems, and individual components as needed.

GONG's engineering team completed an assessment of limited-life issues, major long-term recurring items, and deferred maintenance. A new seal design was developed for the light-feed units and three were rebuilt. Due to an insufficient number of spares, combined with obsolete parts, a new wave-plate amplifier board was designed and certified. Field units and spares will be produced.

Develop and implement a plan to build a complete spare instrument.

An inventory of instrument parts and a spares acquisition plan was completed. Obsolete parts were purchased where possible. In order to accurately project the cost and resources needed to build a replacement instrument, two temporary drafting positions—mechanical and electronics—have been filled to update the complete set of “as built” drawings. The effort began in FY 2004 will be completed in FY 2005. The construction plan has been developed and a review will be held in the December-January 2005 timeframe.

Decrease time required to release data products.

Moving away from workstation-based processing steps to server-based pipeline processing that utilizes shared resources, has significantly decreased overall processing time. The backlog for global frequencies hit the lowest mark ever at 133 days and the processing continues to keep cadence with data collection and the temporal constraints built into the algorithms.

Release online version of the GONG data reduction and processing documentation.

Version 1.0 is available online. The documentation is under version control and will be updated as needed.

Fully implement the automatic image quality assessment software.

The automatic image rejection software package is in its final stage of acceptance testing and should be integrated into the routine production pipeline by January 2005.

Implement high spherical harmonic degree global p-mode processing and local helioseismology.

A work breakdown of this software project was defined in FY 2004, and the effort will require a complete rewrite of the current spherical harmonic transform code and should be operational by mid-FY 2005.

Initiate near-real-time farside imaging.

Significant progress was made on this project during FY 2004. The software will have been ported around the network by the end of 2004 and routine production of near real-time farside maps will follow. Daily full-hemisphere farside maps will be available via the GONG Web site.

Provide near-real-time magnetograms.

After an extensive effort to correct the magnetic zero point using software was unsuccessful, a shift to redesign the magnetogram modulator electronics was investigated. A breadboard design produced excellent results, resulting in a new design. A prototype will be built and tested, and production components will be fabricated, burned in, and deployed before the end of 2005. Magnetogram data products will be defined and the data processing steps, including an additional software zero point correction, will be developed. Routine production of data products will begin early in 2006.

Migrate the data archive to new media.

The raw field data migration from archived 8-mm (Exabyte) tapes to disk has been completed. Final acceptance testing will be completed by the end of 2004, and copied to LTO media for storage. The project was done in-house.

B6. NSO Array Camera*Remote testing of ALADDIN camera controller.*

This has been delayed and made a part of the acceptance testing of the NAC camera.

Completion of science dewar construction.

This has been completed by MKIR.

Integration and testing of controller, dewar and ALADDIN array.

The controller and dewar have been integrated and tests have been run using a multiplexing imaging array (MUX). Tests with the NSO ALADDIN array are expected in early 2005.

Initial science observations at McMP – Spectroscopy.

This has been delayed until 2005.

Development of polarimeter interface software and observing scripts.

This has been delayed until 2005.

APPENDIX C: NSO FY 2005 BUDGET & STAFFING

NSO FY 2005 Budget Summary

	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total Budget
Director's Office	377,185						377,185
Scientific Staff		415,411	773,962	422,296	100,000		1,711,669
Sci Support/Computing		273,614	192,462	690,275		81,606	1,237,957
Instrument Development/Maintenance		521,220	457,562	-	557,200		1,535,982
Telescope Operations		197,368	208,357	1,132,430		231,850	1,770,005
Facilities		629,740					629,740
Administrative Services		242,730		169,999			412,730
Educational & Public Outreach	105,970	131,637	40,000				277,607
ATST Site Testing					-		-
NOAO Business Support	22,821	148,605	396,281	317,025			884,732
ATST Increment (EIS, Mirror, D&D)					-		-
ATST D&D					2,367,630		2,367,630
AURA Management Fee	220,000				45,856		265,856
Program Total	725,977	2,560,326	2,068,624	2,732,025	3,070,686	313,456	11,471,093
Revenues							
NSF ATST D&D from ATM Division					(13,486)		(13,486)
Programmed Indirects	(17,887)						(17,887)
Housing Revenue		(91,000)					(91,000)
Meal Revenue		(16,720)					(16,720)
NSF REU/RET Funding		(40,000)	(40,000)				(80,000)
Air Force Support		(450,000)					(450,000)
NASA Support			(32,000)				(32,000)
Visitor Center Revenue		(50,000)					(50,000)
NSF Astronomy Funding	708,090	1,912,606	1,996,624	2,732,025	3,057,200	313,456	10,720,000
Requested Deltas							
Begin Vendor Final Designs for ATST	2,300,000						
Budget Shortfall - Base Program	250,000						
Postdoctoral Fellowships	120,000						
DST and McMP Controls	130,000						
	2,800,000						

FY 2005 STAFFING SCHEDULE
(In Full-Time Equivalents)

	Director's Office	Sunspot	Tucson	ATST	GONG	SOLIS	Total
Scientists	1.00	4.00	6.00	2.00	6.20	1.00	20.20
Engineering/Science Staff	-	7.50	6.00	6.00	6.75	-	26.25
Administrative Staff	1.00	5.00	-	3.00	2.00	-	11.00
Technical Staff	-	8.25	3.00	2.00	9.75	0.50	23.50
Maintenance & Service Staff	-	9.00	-	-	-	-	9.00
Total Base Program	2.00	33.75	15.00	13.00	24.70	1.50	89.95
AF Supported Science Staff	-	5.00	-	-	-	-	5.00
AF Supported Technical Staff	-	2.00	-	-	-	-	2.00
Other NSF Projects (AO, FTS/CHEM)	-	1.00	1.00	-	-	-	2.00
NJIT Postdocs, Graduate Students	-	1.00	-	-	-	-	1.00
NASA Supported Science Staff	-	-	3.75	-	1.80	-	5.55
NASA Support Engineering Staff	-	-	1.00	-	-	-	1.00
NASA Supported Technical Staff	-	-	0.50	-	-	-	0.50
NATO Science Staff (Postdoc)	-	-	-	-	1.00	-	1.00
Emeritus Science Staff	-	0.50	2.00	-	-	-	2.50
Visiting Scientists	-	-	1.50	-	-	-	1.50
Total Other Support	0.00	9.50	9.75	0.00	2.80	0.00	22.05
Total Working at NSO	2.00	43.25	24.75	13.00	27.50	1.50	112.00

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 and the role they play in solar activity. 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. 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).

– Working in collaboration with M. Eydenberg (MS thesis student, New Mexico Tech) and A. Lopez Ariste (HAO), a PCA interpolation technique has been developed and applied to photospheric Stokes spectral line profiles (Fe I 6301.5 Å). Unlike previous applications of PCA, they consider separate distributions of the PCA components as applied to the source of the underlying plasma, namely the umbra, penumbra and quiet photosphere. They have also considered a PCA-perturbation analysis of the data and how it can assist the interpretation of the results, discuss current challenges faced by the inversion codes and suggest important areas for future development. These results have been accepted for publication in the *Astrophysical Journal*.

– Working in collaboration with M. Eydenberg and H. Uitenbroek, the PCA inversion schemes for non-LTE atmospheres are being established and applied to chromospheric spectra, such as H-alpha. While there are currently many challenges to be faced before the code approaches the efficiency and reliability of other PCA methods, initial results imply that such an approach is definitely feasible and may be of great use for the analysis of Stokes profiles formed in the chromosphere and other regions where the physical parameter distribution is not well-determined. These results are being communicated to a refereed journal.

– 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.

The solar atmosphere offers abundant opportunities to investigate and understand the process of reconnection, and evolution of magnetic fields. In a comprehensive study, Bala uses a series of high-resolution spectroscopic and spectropolarimetric (Advanced Stokes Polarimeter) measurements to understand the structure of twisted flux tubes at the periphery of a sunspot, seeking evidence for reconnection. He traces the twists in magnetic fields through the trail of evidence it leaves at various levels of the atmosphere, as it propagates upward of the photosphere. The diagnostic tools used for this purpose include magnetic and velocity fields at the photosphere and lower chromosphere (H-alpha), 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 high-order NSO AO is aptly suited for this purpose.

– Temporal Variations in the Evershed Flow and Sunspot Oscillations.

Working with A. Pevtsov and S. Olmnschenk (U. Chicago, REU), 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. Their 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. They 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 readied for publication.

3. Solar Activity and Alfvén Waves.

– Bala, S. Keil and C. Watts (New Mexico Tech) will embark on a project to understand the magnetic structure and dynamics of photospheric and chromospheric plage regions in an effort to understand the sustained heating structure of these regions. They will seek to verify theoretical results that the heating is due to Alfvén waves. Preliminary work with graduate student D. Medlin (New Mexico Tech) shows promising results on the search for propagating and sustained waves in transverse magnetic elements, using the ASP data.

4. ATST. (a) Imaging Narrow-Band Filter. Working with G.A. Gary (NASA/MSFC) and B. Robinson (University of Alabama, Huntsville; ATST Fellow), Bala has developed the design and ray-tracing of the telecentric configuration of the triple-Etalon filter. Further progress is being planned on the physical optics configuration and spacing of the Etalon gaps.

5. 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 attempted to make reliable and sustained measurements in G-Band as well as in the Ca II K-line.

6. 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 was chair of the NSO/SP telescope allocation committee (TAC) until August 2004. He now serves as a regular member of the TAC and advises non-NSO users on observing at NSO/SP facilities. He takes supportive responsibility for the NSF-sponsored REU/RET and NSO/SRA programs at NSO/Sac Peak 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 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 and an MS student from New Mexico Tech. He serves on the US Planning and Organization Committee for the International Heliophysical Year (IHY 2007) and is Editor of the *IHY Newsletter*.

Michael Dulick, Associate Scientist**Areas of Interest**

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

Future Research Plans

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

Service

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

Mark S. Giampapa, Astronomer**Areas of Interest**

Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

Recent Research Results

Giampapa completed 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, using the WIYN telescope with the Hydra multiobject spectrograph on Kitt Peak. The survey and variability results will be submitted for publication in FY 2005. 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. Giampapa and T. Simon (U. of Hawaii) have recently used the Keck 10-meter telescope and HIRES spectrograph to measure the projected rotation velocities of selected solar-type stars in M67. The highest spectral resolution attained for these observations was only 4.6 km s^{-1} , which is higher than the solar value of about 2 km s^{-1} . A preliminary examination of the data shows line broadening in the active M67 Sun-like stars to be consistent with the instrumental resolution. Giampapa and Simon have therefore submitted a proposal to use the Subaru 8.2-meter telescope with its high dispersion spectrograph that is capable of resolutions of 1.8 km s^{-1} so that solar-like rotation velocities can be measured.

Finally, Giampapa completed an extensive manuscript as part of the 2004 “Saas-Fee” (of the Swiss Astronomy and Astrophysics Society) in Davos, Switzerland, on *The Sun, Solar Analogues, and Climate*. The Swiss Astronomical Society sponsors this intensive short course intended for postdocs and graduate students. Giampapa’s 111-page manuscript, which will appear in a Springer-Verlag book publication, is entitled, “Stellar Analogs of Solar Activity: The Sun in a Stellar Context.”

Future Research Plans

Giampapa intends to continue working on the M67 project but now within the context of the recently approved, joint University of Arizona/NOAO NASA Astrobiology program. Giampapa is a Co-Investigator in this program where his efforts will 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 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. Giampapa will utilize automated photometric systems along with moderate-to-large aperture telescopes to obtain both spectroscopic chromospheric data and information on associated brightness changes in solar-type stars. During FY 2004, Giampapa hired a postdoc, William Sherry (PhD, Stony Brook), under the auspices of the Astrobiology program to collaborate in this effort. Construction of automated telescope systems to enable the photometric data stream also made significant progress during FY 2004. Observations with one telescope should commence in early December 2004 followed by the next system in January 2005.

M. Giampapa and V. Andretta (U. Naples) are still in the process of completing the analysis of a unique data set of simultaneous He I spectroscopic observations of solar-type stars at 587.6 nm and 1083 nm, respectively. They have developed a technique to estimate fractional active region area coverage on Sun-like stars based on these high-excitation, chromospheric diagnostics. Active region area coverage is considered a key property of the underlying dynamo process.

Service

M. Giampapa serves as the deputy director for the National Solar Observatory, with specific responsibility for the Tucson/Kitt Peak program. In this role, he has overview responsibilities for the scientific and instrument development activities at NSO/Kitt Peak, including the SOLIS project, and the conduct and support for observing programs at the NSO McMath-Pierce 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); 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. As NSO deputy director, 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. Giampapa is an adjunct astronomer at the University of Arizona. 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.

Irene González Hernández, Assistant ScientistAreas of Interest

Local Helioseismology, Ring Diagrams and Holography

Recent Research Results

González Hernández has dedicated most of her time to enhance and support 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.

González Hernández has also analyzed two years of GONG continuous data using a Large-Aperture Ring Diagrams technique to search for solar meridional circulation variability. The preliminary results show a marked correlation between the B_0 solar angle and the presence of a circulation countercell. She has also

spent some of her time trying to modify this local helioseismology technique to reach deeper into the solar interior by using medium- ℓ spherical harmonic rings.

Recently, González Hernández started working on the GONG Farside (holography) project. This project is aimed at using GONG data in the context of space weather forecasting. She will be proposing and developing analysis tools to check and calibrate the solar signal obtained from this technique.

Future Research Plans

González Hernández will continue to devote part of her time to supporting the Ring Diagrams pipeline as required. She will analyze and search for an interpretation of the data obtained regarding the solar meridional circulation variability and, if appropriate, publish it. Progressively, she will allocate more of her time to the Farside project.

Service

González Hernández is involved in Project ASTRO as an astronomer partner. In February 2004, she participated in the astronomical activities with 3rd grade students at Esperanza Elementary School in Tucson. In October 2004, she spent a couple of hours talking about astronomy with the 2nd grade students at Van Buskirk Elementary School.

John W. Harvey, Astronomer

Areas of Interest

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results

During FY 2004, J. Harvey concentrated on SOLIS, correcting known errors in the archive of Vacuum Telescope data, instrumental issues associated with the upgrade of GONG, and preparing proposals for the support of SOLIS operations. This left essentially no time for research. Harvey, with Jeff Sudol, found that all of 15 large solar flares observed with GONG longitudinal magnetic field measurements showed abrupt, large and permanent changes in the photospheric magnetic field under the flares. This work is being prepared for publication.

Future Research Plans

During FY 2005, J. Harvey will continue to concentrate on completion of the SOLIS project and GONG instrument improvements and, consequently, it is again unlikely that any significant research will be accomplished.

Service

J. Harvey performs observatory service as Chair of the NSO/Kitt Peak Telescope Allocation Committee and NSO Scientific Personnel Committee, Instrument Scientist for the GONG project, Telescope Scientist for the KP Vacuum Telescope, and Project Scientist for the SOLIS project. He is co-editor of the journal *Solar Physics*. He serves on the National Research Council Associateship Review Panel. He served on the Comisión Asesora de Investigación of the Instituto de Astrofísica de Canarias (IAC), a strategic plan review panel that provides advice to IAC management approximately every seven years.

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 (NSO 2004 REU student) and J. Harvey on the development of an empirical model to forecast high-speed solar wind using the location of coronal holes. Preliminary results show very good agreement with observed solar wind values. 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) on 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-nm 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.

Henney continued collaboration with F. Hill and H. Jones on 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. In the past year, a 60-page workbook with DASL lessons and RASL resources and recipes was developed and made publicly available as a PDF file. During the past year, 37 students (from three different schools) participated in the RASL project by submitting over 5,500 measurements of active-region positions and areas.

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 three-year unbroken span of Carrington maps of the flows in the outer solar convection zone. A preliminary result is the apparent correlation between kinetic helicity below the surface and the level of flaring activity in an active region on the surface. In addition, the large flare of Oct. 29, 2003 showed an anomalous helicity signal prior to the flare, which vanished after the event. These results point to a physical model of flares resulting from sub-surface “tornadoes”, and could lead to a solar activity predictor.

Along with Howe, Komm, and Frances Edleman (a Yale undergraduate and 2004 REU student), Hill modeled the effect of a magnetic field on the profile of the Ni I 6768 spectral line used by GONG and SOHO/MDI for helioseismic work. The altered profile was then “observed” with a numerical model of the GONG instrument. The results indicated that the observed decrease of the amplitude of the oscillations in active regions could be partially due to magnetically induced profile changes, rather than actual changes in the oscillation amplitude. This suggests that more caution be taken when interpreting activity-related changes in the oscillations.

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 will also extend the spectral line modeling to include different atmospheric heights.

Service

Hill is the ATST site survey scientist and recently completed the final report of the survey. He serves as the GONG Data Scientist, developing 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 European Grid of Solar Observations (EGSO) and Collaborative Sun-Earth Connection (CoSEC) projects. Hill typically supervises several staff, currently four scientists, one data operator, and one programmer. He is a member of the IAU Working Group on International Data Access, and the NSO/Tucson Telescope Allocation Committee.

Rachel Howe, Associate Scientist

Areas of Interest

Helioseismology, the Solar Activity Cycle, Peak Fitting

Recent Research Results

Earlier in 2004, R. Howe published papers with D. Haber and B. Hindman (U. Colorado), F. Hill and R. Komm on width and amplitude variations in GONG and MDI local helioseismic data. She also presented results on global and local helioseismology and flare observations with GONG at the Living with a Star workshop in Boulder, Colorado, the AAS/SPD meeting, the GONG/SOHO meeting at Yale University, and the NSO Workshop on Large-Scale Structures.

Howe is collaborating with M. Rempel (HAO) on simulations of solar rotation variation, and with colleagues at the University of Birmingham, UK, on low-degree helioseismic mode fitting. A collaboration with colleagues at the University of Colorado on the variation of mode frequencies from local helioseismology is also ongoing.

Future Research Plans

Howe intends to continue working on the above areas and also on the temporal variation of the solar rotation.

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 2004 AAS/SPD and the Yale meetings.

Sankarasubramanian Kasiviwanathan, Research AssociateAreas of Interest

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

Recent Research Results

Sankarasubramanian Kasiviswanathan (Sankar) is Co-PI, with Bruce Lites (HAO), of an NSO/HAO collaborative project to develop a new spectro-polarimeter, the Diffraction-Limited Spectro-Polarimeter (DLSP), for the Dunn Solar Telescope (DST). Sankar has developed a new modulator for the DLSP. Sankar also analyzes DLSP data as well as data from the Advanced Stokes Polarimeter (ASP). He has observed and studied the magnetic and velocity field patterns of different active regions with the best spatial resolution that can be achieved with the ASP and the low-order AO system at the DST. He has observed and confirmed the circular convective velocity pattern around solar pores seen in the numerical simulations of small-scale magnetic fields. Sankar also works on the different inversion routines and on retrieving the height variations of physical parameters from the observed Stokes spectra. He is also developing a technique to accurately measure the line-of-sight magnetic fields of active regions.

Future Research Plans

With the DLSP and high-order AO system developed at the DST, Sankar will be able to carry out observations that will achieve the highest possible spatial resolution in vector magnetic field measurements. There is also an effort to get involved with IR spectro-polarimetry with a simple spectrograph as well as with a fiber fed spectrograph. He is also working to achieve simultaneous magnetic field observations in the optical as well as in the IR wavelength. Sankar is developing a novel technique to observe line-of-sight magnetograms over a range of visible wavelengths without the influence of the telescope polarization. He is also interested in developing a new concept for a tunable Stokes polarimeter.

Service

Sankar was the lead organizer for the 2004 NSO Workshop on "Large-Scale Structures and Their Role in Solar Activity" that was held at Sac Peak on October 18-22. He was a mentor to two of the Summer 2004 REU students. He also reviewed two papers for the *Astrophysical Journal*.

Stephen L. Keil, NSO DirectorAreas 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 is planned for February 2005 in Paris.

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.

Christoph U. Keller, Associate AstronomerAreas of Interest

Ground- and space-based astronomical telescopes and instruments (high-precision imaging and spectroscopic polarimetry, large astronomical telescope design and development, CMOS and CCD imaging detector development for polarimetry, adaptive optics using micro-electro-mechanical system (MEMS) deformable mirrors and standard PCs, detector development for hyper-spectral imaging, advanced image reconstruction techniques, innovative software concepts for instrument control and astronomical data analysis), observations of solar magnetic fields from radio to X-ray wavelengths, interpretation of solar magnetic field observations using radiative transfer calculations and numerical magneto-hydrodynamic simulations, polarimetry in general including applications to aerosol measurements from satellites and land-mine detection

Recent Research Results

Solar faculae appear close to the solar limb as bright, small-scale features that are related to magnetic fields. Faculae have been known since telescopes have been pointed at the Sun, but their origin has never been clearly revealed. Keller, in collaboration with Manfred Schüssler, Alexander Vögler, and Vasily Sakharov of the Max-Planck-Institute for Solar System Research analyzed ab-initio three-dimensional simulations of non-gray radiative magneto-convection in the solar surface layers and showed that the simulations reproduce the observed small-scale features. In particular, the simulations qualitatively reproduce all features seen in the observations. The simulations reveal that the excess brightness of the faculae comes from a thin layer (about 30 km thick), which is embedded in the steep density gradient at the interface between the magnetic and the non-magnetic atmosphere. The dark, narrow lanes often associated with faculae occur at the opposite side of the magnetic flux concentration and are due to an extended layer with lower-than-average temperature.

Future Research Plans

During FY 2005, Keller will concentrate on producing the first science results from the vector magnetic field data collected by the SOLIS vector spectromagnetograph (VSM). He expects to leave NSO for Utrecht University in July 2005.

Service

Keller is the telescope scientist for the McMath-Pierce Telescope and the SOLIS VSM. He is engaged in various ATST activities and is the NSO representative on the Frequency Agile Solar Radio telescope (FASR) project. Keller is a member of the local and joint-site project review committees.

Shukirjon Kholikov, Assistant Scientist*Areas 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 Scientist*Areas of Interest*

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

Recent Research Results

Komm continues to perform research in helioseismology. 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 working with F. Hill and R. Howe on the variation of mode width and amplitude, which provide information about mode damping and excitation. He is also studying the relation between solar oscillations, granulation, and magnetic activity (in collaboration with Victoria Astley, an REU summer student he mentored in 2003).

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 continue studies of the solar cycle variation of mode parameters of solar oscillations with a focus on the mode background amplitude and other indicators

of mode physics. He will continue to study advanced time-series analysis techniques such as empirical mode decomposition and Hilbert transform (in collaboration with M. Roth, Freiburg, Germany) in order to evaluate their usefulness for helioseismology. With these techniques, Komm will study in greater detail the relation between p -mode energy and magnetic activity. He will continue to study the relation between solar oscillations, granulation, and magnetic activity.

Service

Komm continues as a participant in Project ATSTRO.

John W. Leibacher, Astronomer

Areas of Interest

Helioseismology, Atmospheric Dynamics

Recent Research Results

The global structure results from GONG continue to offer new insights into the sub-surface evolution of the solar cycle, and they are being complemented by various local analyses as well as magnetic field measurements, and even some remarkable white-light flare observations.

Future Research Plans

While Leibacher continues to devote the majority of his efforts to assuring GONG's technical and scientific success, work is underway on testing models of solar internal dynamics and the dynamo using new methods for measuring sub-surface meridional flows, and applying them to the entire, continuous GONG dataset. Ideas about the observational signature of the convective excitation of p -mode oscillations are being pursued with data from GONG as well as the SOI/MDI instrument onboard the SOHO spacecraft with collaborators at the Institut d'Astrophysique Spatiale (Orsay).

Service

Leibacher serves as the director of the Global Oscillation Network Group program. He has been a mentor to an undergraduate physics student for the past three 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, as well as a member of the NAS/NRC Committee on PI-Led Missions. He is co-organizing an SPD sponsored summer school on helioseismology, the 2005 NSO summer workshop, and proposals for IAU meetings on helioseismology in 2006.

Matthew J. Penn, Associate Astronomer

Areas 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 completed the tasks assigned to the ATST Coronal Working Group, and analyzed the ATST Sky Brightness Monitor site survey data for the ATST Site Survey Working Group; papers describing these efforts have been published in various journals. Penn has worked with the University of Hawaii IfA group in the development of the ATST near-IR spectropolarimeter instrument and continues this work.

Penn has been working on the NSO Array Camera (NAC) project; the camera electronics are complete and the dewar has been constructed. The NAC components are currently being integrated at MKIR in Hilo, HI, and will likely be shipped to Tucson in early 2005.

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

A. Pevtsov worked with researchers from other institutions on several studies including properties of X-ray and EUV bright points, properties of transequatorial coronal loops, and role of the large-scale magnetic reconnection in the coronal heating.

A study of transequatorial loops (TLs) has demonstrated that some TLs have properties that are inconsistent with their definition as a loop; these TLs may represent current sheets or magnetic separators. Spatial distribution of TLs suggests that these structures may develop within complexes of activity. Some coronal mass ejections may be associated with eruption of transequatorial loops.

A correlation between AR twist and tilt was studied using vector magnetograms from Haleakala Stokes Polarimeter and Mt. Wilson full-disk longitudinal magnetograms from 1988-1995. It was found that the regions obeying Joy's law (describing AR tilt relative to equator) do not show significant correlation between magnetic field writhe and twist, in agreement with predicted consequences of convective buffeting of initially un-twisted flux tubes (-effect). On the other hand, the regions deviating from the Joy's law show significant correlation between their tilt and twist. For these regions, there may be an additional mechanism (e.g., sub-surface dynamo, or buoyancy instability and flux tube formation) responsible for imparting initial twist.

Pevtsov and his colleagues developed an automated procedure to identify X-ray and EUV bright points. This procedure was applied to SOHO/EIT data to study various properties of bright points (BP) near the minimum of solar activity. It was found that the distribution of BPs exhibits large-scale structures that might be related to magnetic areas with different degree of flux imbalance. Latitudinal distribution of BPs shows an enhancement at active region latitudes. The total number of BPs does not change between 1996 and 1997, but it increases by about 20% in 1998.

To understand the role of large-scale reconnection in heating of solar corona, Pevtsov and one of his summer students studied the evolution of magnetic flux and X-ray brightness of quiet Sun corona in vicinity of an emerging active region. They found that as active region emerges, the corona increases its brightness at the large distance from emerging flux. They observed increase in temperature but no significant changes in properties of magnetic flux on quiet Sun around the emerging region. They interpreted their findings as coronal heating associated with magnetic reconnection between new and pre-existing flux systems.

Future Research Plans

A. Pevtsov will continue to study the properties of X-ray and EUV bright points and associated photospheric bipoles, the role of magnetic field in coronal heating, and the relationship between solar drivers and geomagnetic storms. Other research plans include the study of helicity of rotating sunspots, evolution of delta-spots, plasma flows in and around emerging active regions, and the origin of periodic structures in quiescent prominences.

Service

A. Pevtsov supervises the NSO/SP technical librarian, reviews NSO/SP observational proposals, and participates in SP/TAC meetings. He served as NSO/SP colloquium Chair until the end of 2004, and beginning in the fall of 2004 assumed responsibility as a co-site director of the NSO REU program. He also participates in ATST Science Working Group meetings. Pevtsov supervised two summer students and an RET teacher during summer 2004. During FY 2004, he served as a reviewer for four professional journals (*Astrophysical Journal*, *Astronomy and Astrophysics*, *Journal of Atmospheric and Solar-Terrestrial Physics*, and *Solar Physics*), reviewed one chapter of the textbook published by PRAXIS Publishing, and reviewed scientific proposals for NASA, NSF, and the Grant Agency of the Academy of Sciences of Czech Republic. He conducted several public tours at NSO/Sacramento Peak and gave one public lecture for the Enchanted Skies Star Party in Socorro, New Mexico. He served as a member of the Local Organizing Committee and the Scientific Organizing Committee for two meetings: the US Planning Workshop for the 2007 International Heliophysical Year and Co-Chair of the 22nd NSO International Workshop on “Large-Scale Structures and their Role in Solar Activity.” In collaboration with D. McKenzie (Montana State U.), he developed a new graduate-level course on Observational Astrophysics for 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 fluxtubes. 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.

With the submission of the final site survey report by the Site Survey Working Group and the site recommendation by the Science Working Group, the ATST site survey was brought to a successful conclusion.

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 has recently been appointed to 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 a summer 2004 student on IBIS data. 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 Haleakala.

Clifford Toner, Associate Scientist

Areas of Interest

Global and Local Helioseismology, Image Restoration, Data Analysis Techniques

Recent Research Results

C. Toner has devoted much of his time to the support of the GONG++ data reduction/analysis pipeline. Ring-diagram analyses have shown the importance of obtaining accurate orientation estimates for the site images—incorrect values lead to spurious results. Toner is currently using MDI as a fiducial "site" in order to accurately align the entire GONG Network and remove spurious "wobbling" of the merged images. He is developing an approach that utilizes regular noon drift-scans to maintain the alignment of the Network after MDI is shut down. Automating the processing of the drift-scans once they are in Tucson is nearly ready.

Toner led a small group of people who worked to bring the June 8, 2004 Venus Transit—as observed by the GONG Network—to the NSO Web page in near-real-time. A CD, which includes jpegs of all of the clear-

time images from the Venus transit, as well as jpegs of the images from the Nov. 15, 1999 and the May 7, 2003 Mercury transits, has been produced. The images are also posted on the GONG Web site.

Future Research Plans

Toner will complete the automation of the drift-scan processing, then formally write up the procedure for publication.

Service

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

Han Uitenbroek, Associate Astronomer

Areas of Interest

Radiative Transfer Modeling and 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.

Using a forward modeling approach, calculating accurate spectra from a given model, Uitenbroek continued his investigation of the accuracy of magnetic field measurements in the solar atmosphere. Results from forward modeling can be used in several ways. Most importantly, some of the by-products of a forward calculation, like the formation height and contribution and response functions of a given spectral feature serve to show to what region and conditions the spectral feature is sensitive to. Secondly, the resulting spectra may be used in a forward-backward approach where they are analyzed as observations with a given inversion method. The reliability of such a method can then be estimated by comparing the recovered values of physical parameters with the actual values in the original model.

Together with K. S. Sankarasubramaniam and NSO/SP summer 2004 intern Michelle McMillan, Uitenbroek investigated the reliability of several inversion methods, ranging from a simple center-of-gravity determination of the line-of-sight (LOS) magnetic field to more advanced methods like the ones implemented in the MELANIE (Milne-Eddington Line Analysis using an Inversion Engine), LILIA (LTE Inversion based on the Lorien Iterative Algorithm), and SIR Stokes Inversion based on Response Functions) code. The calculated emergent spectra for two the Fe I lines at 630.25 and 1564.85 nm through a two-dimensional cross section from a mageto-hydrodynamic simulation were inverted with these four methods and the obtained values of the LOS magnetic field and velocity were compared with the true values in the slice. Analysis of the results showed that the inversion of spectra needs to be regarded with much skepticism, especially when complicated magnetic field structures are present along the line of sight.

A popular method for tracking small-scale features is narrow-band imaging in the G-band with typical passbands of 1-nm FWHM. This technique is optimal in combination with image improving techniques like adaptive optics and post facto image reconstruction. A drawback of G-band imaging is that it does not provide measurement of the magnetic flux, which has to be obtained from simultaneous and co-spatial magnetograms in magnetically sensitive atomic lines. It would be preferable if magnetic flux could be measured in precisely those spectral lines that make up the G-band. Most of the opacity in the G-band is due to electronic transitions in the A-X band of the CH molecule with added contributions from atomic lines of different elements. The CH molecular lines are susceptible to the Zeeman effect in the presence of

an external magnetic field and may produce polarized radiation that can be analyzed to infer the properties of the field. When the resulting polarization is calculated in realistic one- and two-dimensional models of the solar atmosphere with realistic field strengths, the detection of magnetic fields through analysis of the Zeeman effect in CH lines indeed seems to be possible. Together with K.S. Balasubramaniam at NSO Uitenbroek has obtained spectra of Stokes I and V in the G band. These spectra clearly show the presence of the Zeeman effect in the CH lines, confirming the theoretical calculations. Further observations with an improved instrumental setup are planned for this year.

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-alpha 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.

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.

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. The code will also be used to investigate the viability of the calcium infrared triplet lines for chromospheric magnetic field measurements. Together with Balasubramaniam at NSO, Uitenbroek will attempt further observations of the polarization in the G-band due to CH lines. The radiative transfer code will also be used to investigate the linear polarization properties of the NaI D lines due to scattering.

Service

Uitenbroek is involved in the infrared camera effort at the Dunn Solar Telescope. He serves as the Chair of the Telescope Allocation Committee at Sac Peak, and also oversees the science exhibit in the Sunspot visitor center. About ten 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 MAINTENANCE PLAN FY 2005

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 2005 facilities maintenance projects at each site are described below.

Sacramento Peak

The FY 2005 NSO/SP budget includes approximately \$20K for items above the normal reactive maintenance program and approximately \$20K from housing revenues above the normal maintenance for housing. We also expect to have carryover funds of approximately \$65K. Most of these funds will be reserved for possible renovation of our sewage plant. Our State Environmental Department permit is due for renewal in 2006 and negotiations are on-going to determine the required upgrade to the facility to improve our output. Smaller projects that will be undertaken include replacement of the purchasing van, upgrading our cable television system and exterior painting of several commercial buildings and residences. 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 2005 Projects

(Dollars in Thousands)

<i>Project</i>	<i>Est Cost</i>
Sewage Plant Upgrade	125
Cable TV Upgrade	16
Commercial Painting	10
Housing Painting	10
Vehicle Replacements	40
Cloudcroft Facility	50
Total	\$251

Sewage Plant Renovation: The sewage plant that treats all the sewage generated at Sac Peak must be repermited in 2006. Changes in the requirements established for the facility may require a substantial upgrade. Funds have been reserved to assist in this upgrade.

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

Cloudcroft Facility: NASA spent over \$175K in renovation of the main telescope building at the Cloudcroft Telescope Facility. Other buildings, in particular the RCA building 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: Several residences require exterior repainting. These will be dealt with on an as needed basis by our current staff and summer helpers.

Vehicle Replacements: Our vehicle replacement plan includes the need to replace the Purchasing van and one of our staff vehicles, in that order. Staff vehicle will be deferred if funds are not available.

Accomplished in FY 2004:

- Reroofed auto mechanic shop
- Began sewage plant renovation/upgrade
- Completed dust remediation project at DST
- Replaced emergency generator
- Upgraded electrical transmission system
- Completed ADA compliant apartment and main lab ramp
- Installed emergency exit doors and lighting at main lab

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 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

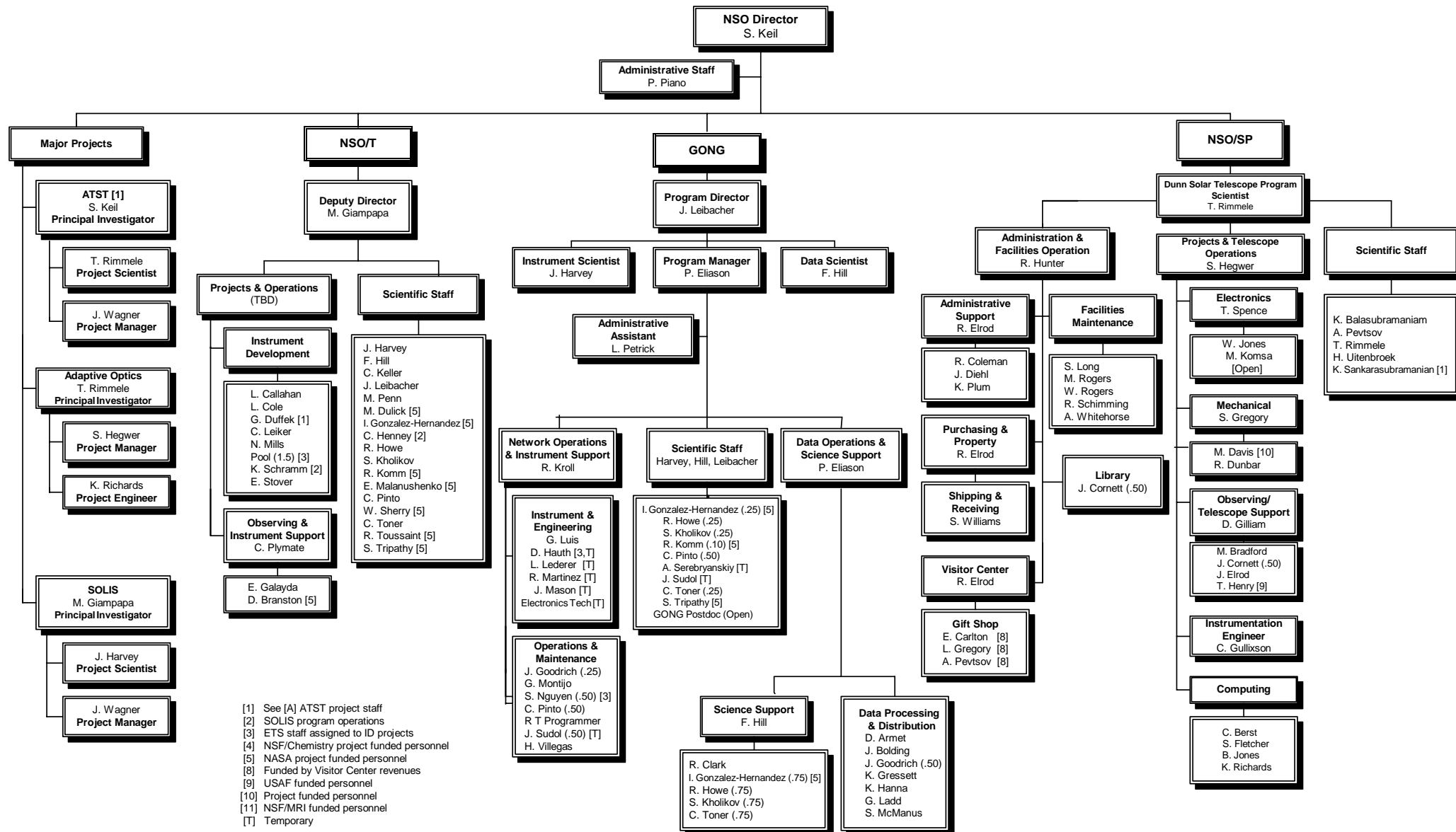
Stephen L. Keil	NSO Director; ATST Project Principal Investigator
Mark S. Giampapa	NSO Deputy Director; SOLIS Principal Investigator
Thomas R. Rimmele	ATST Project Scientist; Dunn Solar Telescope Program Scientist
John W. Harvey	SOLIS Project Scientist
Jeremy J. Wagner	ATST Project Manager; SOLIS Project Manager
Stephen Hegwer	Project and Telescope Manager, Sacramento Peak
John W. Leibacher	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 & Facilities
James Tracy	Controller
Larry Daggert	Engineering & Technical Services (ETS) Manager
Steve Grandi	Computer Infrastructure Services (CIS) Manager
Sandra Abbey	Human Resources Manager
John Dunlop	Central Facilities Operations & Kitt Peak Facilities Manager
Doug Isbell	Public Affairs & Educational Outreach Manager

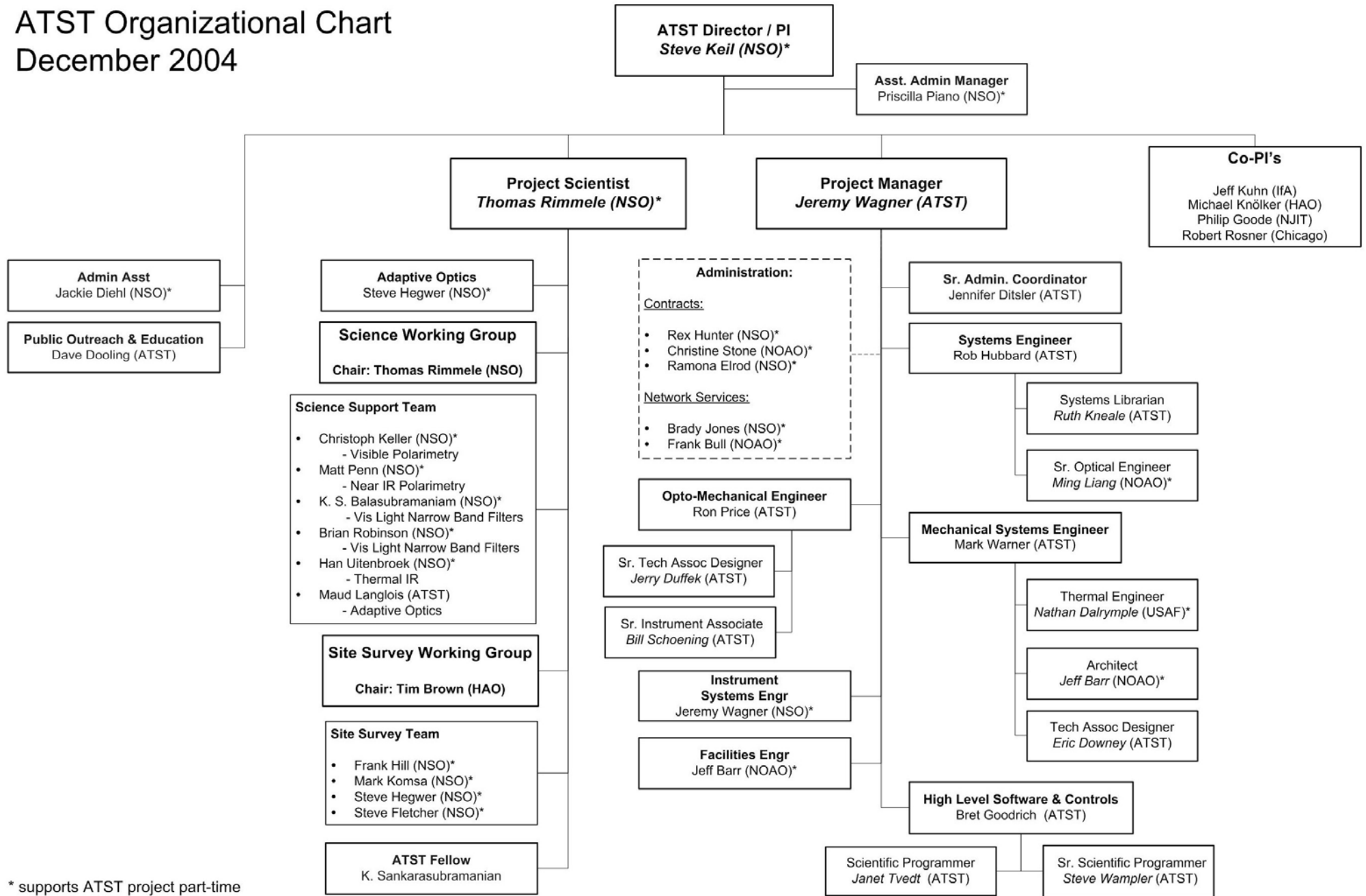
APPENDIX G: ORGANIZATIONAL CHARTS

NATIONAL SOLAR OBSERVATORY



ATST Organizational Chart

December 2004



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
CoDR	Concept Design Review
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
EIS	Environmental Information Services
EPO	Educational and Public Outreach
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
GB	Giga Bytes
GONG	Global Oscillation Network Group
GOLF	Global Oscillations at Low Frequencies
GSFC	Goddard Space Flight Center
HAO	High Altitude Observatory
HT	Hilltop Telescope
IAC	<i>Instituto de Astrofísica de Canarias</i>
ICC	Instrument Computer Control
ICD	Interface Control Document
IBIS	Italian BI-dimensional Spectrometer
IFA	Institute for Astronomy (University of Hawaii)
IHY	International Heliophysical Year
IR	Infrared
IRAF	Image Reduction and Analysis Facility (NOAO)

APPENDIX H: ACRONYM GLOSSARY

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
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
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
PAEO	Public Affairs and Educational Outreach
PCA	Principal Component Analysis
PSF	Point Spread Function
RASL	Research in Active Solar Longitudes
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
SCOPE	Southwest Consortium of Observatories for Public Education
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
SXT	Soft X-ray Telescope (<i>Yohkoh</i>)
TAC	Telescope Allocation Committee
TB	Tera Bytes

APPENDIX H: ACRONYM GLOSSARY

TCS	Telescope Control System
TL	Transequatorial Loop
TLRBSE	Teacher Leaders in Research-Based Science Education
UBF	Universal Birefringent
TRACE	Transition Region and Coronal Explorer
UCSD	University of California, San Diego
UV	Ultraviolet
VMG	Vector Magnetograph
VSM	Vector Spectromagnetograph
VSO	Virtual Solar Observatory
WBS	Work Breakdown Structure
WWW	World Wide Web
<i>Yohkoh</i>	“Sunbeam,” Satellite project of the Japanese Institute of Space and Astronautical Sciences
ZIMPOL	Zürich IMaging POLarimeter