

ANNUAL PROGRAM PLAN  
OF THE  
NATIONAL SOLAR OBSERVATORY  
*FY 2008*

NSO

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## MISSION

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

*NSO accomplishes this mission by:*

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

## RESEARCH OBJECTIVES

The broad research goals of NSO are to:

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

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# I INTRODUCTION

Major components of the National Solar Observatory (NSO) strategic planning include:

- Developing the 4-meter Advanced Technology Solar Telescope (ATST) on behalf of, and in collaboration with, the solar community;
- Development of the adaptive optics (AO), multi-conjugate AO (MCAO), and infrared (IR) technology needed for the ATST;
- Operating the current high-resolution and IR flagship facilities and maintaining their competitiveness through AO, MCAO and state-of-the-art instrumentation until the ATST is commissioned;
- 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 community use. 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.

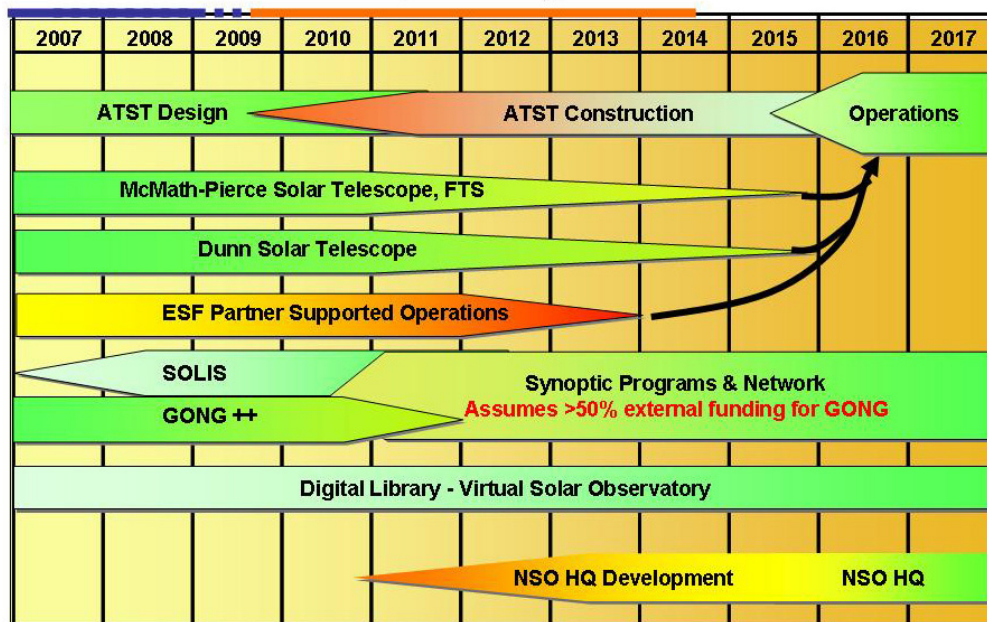
The FY 2008 program outlined in this plan will continue to advance these strategic objectives. The plan presents in detail what NSO proposes to accomplish in FY 2008 with the \$11,300K budgeted from the NSF Division of Astronomical Sciences for solar physics, and with the additional funds received from NSO's partnering organizations. The plan also discusses how the 2008 program supports the strategic goals of solar physics, discusses planning for NSO in the ATST era, how NSO will transition its programs, taking into account the advice of the Senior Review, and discusses the funding requirements for moving forward into the ATST era.

The sections that follow describe the NSO plan to renew its facilities, ongoing operations, and new instrumentation. Included are NSO's response to the Senior Review, 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 in education and public outreach, including the training of solar astronomers, 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.

The report of the NSF Senior Review Committee, while supporting the plans for ATST and consolidation of the NSO staff, contains recommendations that would have serious impacts on the NSO long-range strategic planning and ground-based solar capabilities in the US. Implementing the Senior Review recommendations also involves considerable short-term costs. The NSO is planning to phase out its operations on Kitt Peak and Sacramento Peak in order to generate operational support for ATST and to establish a new NSO Headquarters that consolidates the current staff at Sunspot and in Tucson. The Senior Review recommendation to move forward with these processes even before ATST is built would seriously undermine the US solar community. Thus, while NSO will continue to transfer resources to ATST development efforts, we will work with the NSF to ensure that existing first-rate ground-based facilities are adequately maintained to support the solar community and the development of ATST technologies.



**Figure II-1.** Strategic road map of NSO facilities.

Figure II-1 summarizes the road map for evolving NSO facilities and major programs that support the solar physics community. During FY 2007, the ATST, following its consideration by the National Science Board (NSB), moved from the NSF Major Research Equipment and Facility Construction (MREFC) readiness phase into the



MREFC approval phase. The project is working with the NSF to identify funds for continuing ATST development in 2008 to facilitate a smooth transition to construction in 2009. The entire NSO road map is keyed to the start of ATST construction in 2009 and to receiving ATST funding at a rate that allows maintaining the planned schedule. The NSO has been shifting manpower to ATST development in a way that permits continued operations and advancement of solar instrumentation that will be required in the ATST era. Additional funding to continue instrumentation efforts at U.S. partner institutions is needed and requested in Sections II-1.1.9 (page 10) and in Table V-10 in Section V-3.3.1 (page 37). Moving into the ATST era, establishing a remote operations center on the island of Maui—assuming ATST is successfully located on Haleakalā—consolidation of NSO staff at a single headquarters site, and divestiture or removal of existing facilities will require substantial one-time funding increments that are not available in the current NSF/AST budget. Thus, the road map we have laid out is subject to change due to funding availability and other variables, many of which are not under NSO control.

As NSO operates adaptive optics systems and develops interfaces between the AO systems and new diffraction-limited instrumentation, we are gaining the experience needed to operate the high-resolution modes of the ATST. The AO program is exploring multi-conjugate AO concepts using the Dunn Solar Telescope (DST). Funding was obtained under contract with Lockheed to support the Hinode mission with high-resolution spectral polarimetry. The eventual implementation of MCAO on the ATST will be needed to extend high-resolution imaging to the full ATST field of view. Advances in infrared magneto-spectropolarimetry are under development at the McMath-Pierce Solar Telescope (McMP), currently the only large-aperture telescope with thermal-IR capabilities.

NSO has been collecting SOLIS vector spectromagnetograph (VSM) data over the past few years and has released quick-look vector magnetograms of active regions. SOLIS VSM data are being used extensively in support of the Hinode mission. These data are providing the information needed to debug this very complex instrument and to develop the algorithms that will eventually allow rapid reduction and calibration of the data. The data can then be pipelined into the NSO Digital Library with its Virtual Solar Observatory (VSO) links. When this effort is completed, the vector data will become available to users, just as the line-of-sight magnetic field data from the VSM are now available. NSO is now negotiating with Germany, Spain and Algeria for development of a second SOLIS VSM station and will seek a third partnership to establish a three-station SOLIS network. The SOLIS Integrated Sunlight Spectrometer (ISS) has been calibrated and the final SOLIS instrument, the Full-Disk Patrol (FDP), will be installed in 2008.

GONG continues to operate its new high-resolution cameras, producing routine far-side imaging and near-real-time magnetic field maps, which have applications for space weather prediction. GONG has obtained support from the NASA Living With a Star (LWS) program and the Solar TERrestrial RELations Observatory (STEREO) mission to support its scientific and near-real-time operations, and will continue to seek additional external funding as recommended by the Senior Review.

In addition to operating major facilities for the solar community, NSO conducts many 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. NSO actively participates in the education of undergraduate and graduate students, especially in the area of instrumentation. NSO also supports several K-12 programs. While these service 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

NSO is working with the solar community to develop the next generation solar telescope that will enable observations of fundamental astrophysical processes at their intrinsic scales. The major new ground-based project in solar physics is the development of the 4-meter Advanced Technology Solar Telescope. A complete description of science goals, and project information, can be found at <http://atst.nso.edu/>.

The ATST was first proposed to NSF as a design and development project in 2001. Review of the proposal showed that the community had developed an excellent science case for ATST and the design and development (D&D) phase was funded. In late 2003, the ATST project submitted a construction proposal to NSF. After another highly successful review, it was determined that ATST should be the first project to follow the newly developing MREFC guidelines, which were being established to meet congressional concerns. NSF conducted an ATST cost review, which resulted in ATST entering the MREFC “readiness” phase. In the fall of 2006, a successful preliminary design review (PDR) was held and it was determined that

ATST was ready to move into the next phase. At the August 2007 meeting of the National Science Board, it was recommended that the NSF should consider submitting ATST for funding, moving it from readiness into the approval phase. NSF and the ATST project are now pursuing a final Environmental Impact Statement (EIS) for the proposed construction site on Maui and are making preparations for a final baseline review.

Table 1.1-1. ATST Science Working Group	
Thomas R. Ayres	University of Colorado, CASA
Thomas E. Berger (Ch.)	Lockheed Martin, Solar & Astrophysics Laboratory
Tim Brown	High Altitude Observatory
Mats Carlsson	University of Oslo, Norway
Gianna Cauzzi	Arcetri Observatory, Italy
Manuel Collados-Vera	Instituto de Astrofísica de Canarias, Spain
Craig DeForest	Southwest Research Institute
Lyndsay Fletcher	University of Glasgow, United Kingdom
G. Allen Gary	NASA Marshall Space Flight Center
Sarah Gibson	High Altitude Observatory
Leon Golub	Harvard-Smithsonian Center for Astrophysics
Donald E. Jennings	NASA Goddard Space Flight Center
Philip G. Judge	High Altitude Observatory
Christoph U. Keller	Utrecht University
Jeffrey R. Kuhn	University of Hawai'i, Institute for Astronomy
Haosheng Lin	University of Hawai'i, Institute for Astronomy
Dana Longcope	Montana State University
Thomas R. Rimmele	NSO
Luis Bellot Rubio	Instituto de Astrofísica de Andalucía, Spain
Michael Sigwarth	Kiepenheuer Institut für Sonnenphysik, Germany
Hector Socas-Navarro	High Altitude Observatory
Robert F. Stein	Michigan State University
Yoshinori Suematsu	National Astronomical Observatory of Japan
Haimin Wang	New Jersey Institute of Technology/Big Bear Solar Observatory

### 1.1.1 ATST Science Working Group and Science Requirements

The ATST Project Scientist, Science Working Group (SWG), and in-house science team have carefully laid out the ATST science goals and developed instrument specifications required to meet these goals. The SWG (see Table 1.1-1) has both US and international members who report to and advise the Project Scientist and Project Director. Under the leadership of the Project Scientist, the SWG and in-house science team produced

a Science Requirements Document (SRD) (#SPEC-0001), and contributed to the science write-up for the ATST construction proposal. The SWG recommended the primary and alternate sites for the ATST based on the site survey data.

### ***1.1.2 ATST Project Engineering and Design Progress***

The ATST project accomplished several major milestones during this past year, including successful design reviews and workshops focused on the M1 assembly, enclosure, telescope control system (TCS) and common services software. The ATST project team continues to draw from a broad range of resources, which, in addition to new hires, include members of the NSO staff, individuals from other organizations, and Co-PI teams that review instrumentation, operations, and design issues.

#### **1.1.2.1 Construction-Phase Planning**

Construction-phase management and systems engineering efforts were focused on requirements for the construction phase including the integration, testing, and commissioning phase. These efforts were in addition to management and systems engineering efforts that supported the design phase tasks. The project has considered a range of possible subcontracting options during the construction phase and developed these options with interface requirements and project organization in mind. During the past year, the interface control document (ICD) system and the work breakdown structure (WBS) were again refined through the construction phase. As in the design phase, the WBS is consistent with the subsystems, has an accounting number system that matches both the WBS and ICD organization, and includes the detailed plans and schedules for the project through the construction phase and into early operations. Current lead engineers and team members assigned to each of the major WBS design elements are shown in Table 1.1-2.

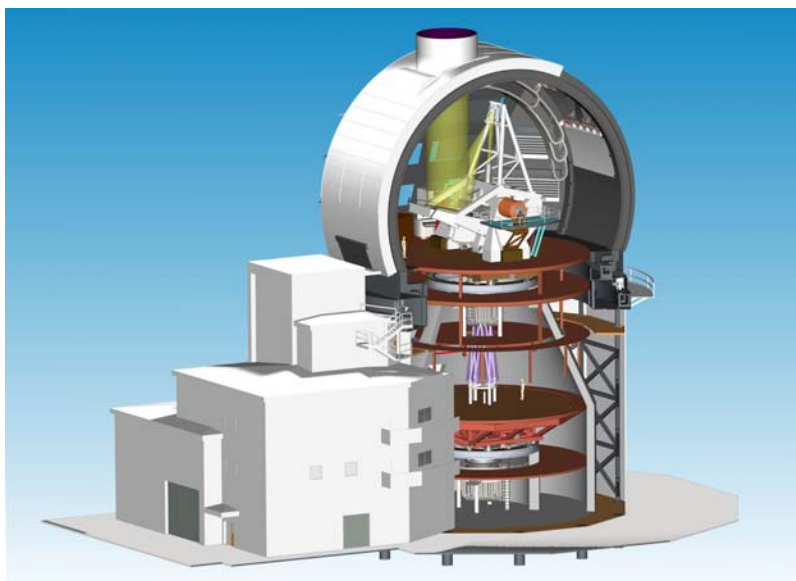
Funds have been budgeted to each of the major WBS elements for both design and construction phases, and design-to-cost “targets” were established for each WBS element. A conservative design scenario was used, without contingency, to establish these targets. It included estimates and design evaluation efforts from industry and partners. Contingency, based upon risks and feedback from industry after the conceptual design review (CoDR), is held centrally in the project management WBS to help focus each engineering manager on design-to-cost targets that were established early.

#### **1.1.2.2 Current Design Activities**

Current design activities include producing mechanical and optical layouts for the transfer optics; finalizing

<b>TABLE 1.1-2. ATST Engineering Responsibilities</b>	
<b><i>Systems Engineering</i></b>	Eric Hansen
	Rob Hubbard
<b><i>Telescope Assembly</i></b>	Mark Warner
Telescope Mount	Mark Warner
M1 Assembly	Eric Hansen
M2 Assembly	Eric Hansen
Feed Optics	Eric Hansen
Thermal Systems	LeEllen Phelps
Stray and Scattered Light Control	Rob Hubbard
<b><i>Wavefront Correction</i></b>	Thomas Rimmele
	Steve Hegwer
	Kit Richards
<b><i>Instrument Systems</i></b>	Jeremy Wagner
	Rob Hubbard
<b><i>High-Level Controls and Software</i></b>	Bret Goodrich
	Steve Wampler
<b><i>Enclosure</i></b>	Mark Warner
	LeEllen Phelps
<b><i>Support Facilities (includes infrastructure items)</i></b>	Jeff Barr

and tolerancing the instrument feed to the coudé lab; updating the telescope structure and enclosure thermal design and analysis for the interface to the coudé lab, and conducting performance updates based upon the Haleakalā site testing data. The current design is shown in Figure 1.1-1. The design includes the simplified one-level coudé instrument area and feed arrangement. The feed for instrumentation associated with this is more compact and simpler to direct to multiple instrument stations.



*Figure 1.1-1. Current ATST facility design with enclosure vents, telescope, and large single-coudé lab.*

Preliminary instrument design efforts and other activities have continued with the Co-PI teams and partners. The following efforts are underway:

- ◆ High Altitude Observatory (Visible Light Polarimeter Design; Near IR Polarimeter Contributions).
- ◆ University of Hawai'i (Near IR Polarimeter Design (Lead).
- ◆ New Jersey Institute of Technology (Tunable IR Filter Design).
- ◆ Lockheed-Martin (Visible Broadband Imager Contributions).
- ◆ NASA Marshall Space Flight Center (Visible Tunable Filter/Polarimeter Design, working with NSO and KIS).
- ◆ Kiepenheuer Institut für Sonnenphysik (Visible Tunable Filter (lead), working with NSO and NASA).

### ***1.1.3 ATST Management Activities***

Current management activities include continued planning for various potential scenarios to bridge funding gaps between the D&D phase and the construction phase. Scenarios have been developed, in consultation with NSF, for covering needs of the project, given the delay in the start of construction to FY 2009 at the earliest. If a delay beyond 2009 is necessary, this process will be revisited.

The overall top-level schedule is shown in Figure 1.1-2. It assumes that construction will begin in FY 2009.

### ***1.1.4 ATST Site Selection***

The ATST site survey, which began in November 2001, was successfully concluded in January 2005. Six sites were evaluated in detail: Big Bear Solar Observatory, California; Haleakalā, Hawai'i; San Pedro Martir, Mexico; Panguitch Lake, Utah; La Palma, Canary Islands, Spain; and Sacramento Peak, New Mexico. The instrumentation placed at each site consisted of a solar differential image motion monitor, scintillometer array, dust monitor, weather station, and miniature coronagraph. The site survey data were used to compare the test sites in terms of statistics of the fraction of clear time, seeing, dust levels, sky brightness, water vapor, and weather.

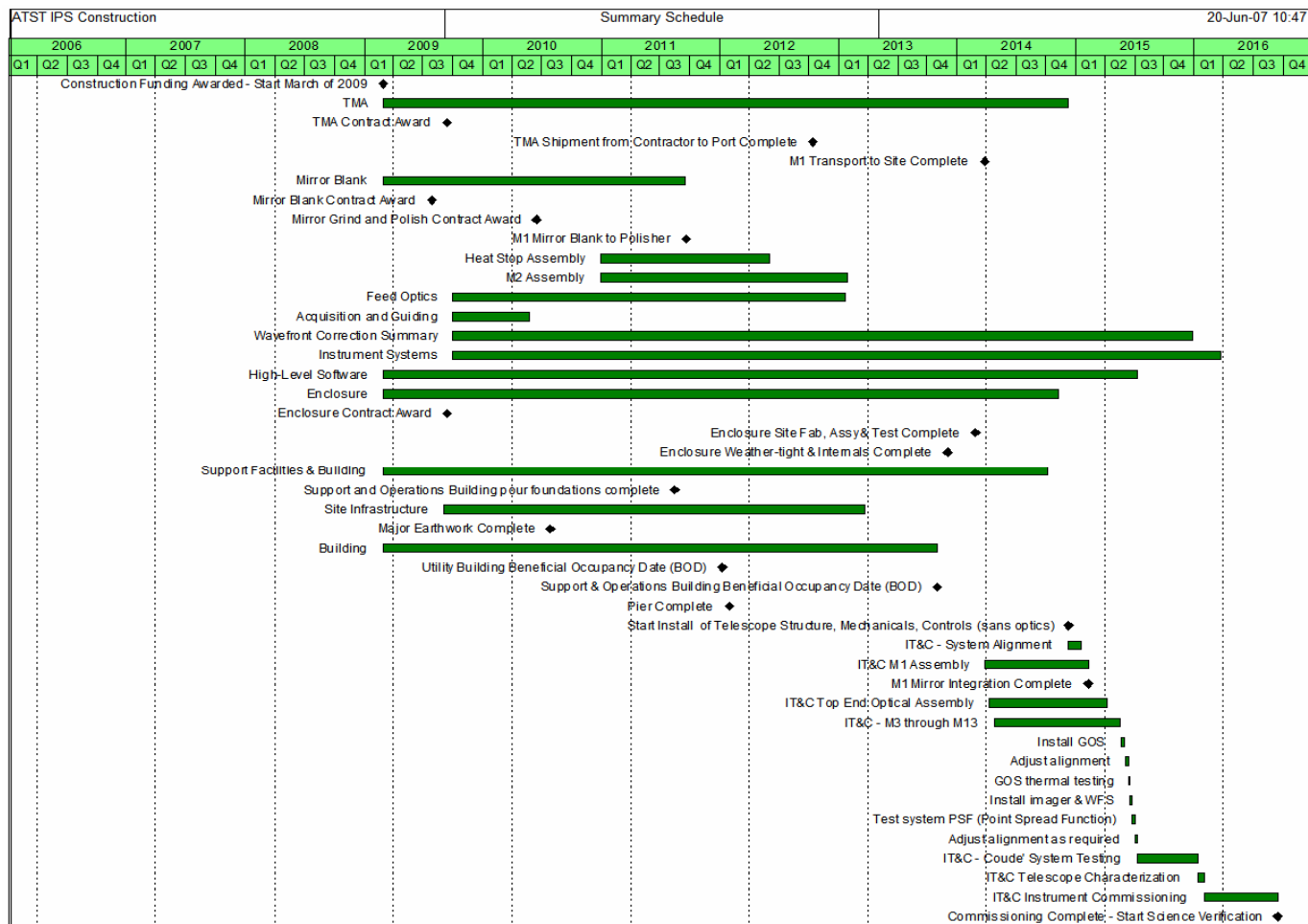


Figure 1.1-2. ATST high-level schedule.

Testing was concluded at each of the six sites in early 2004. The Site Survey Working Group (SSWG) studied the results and prepared its final report for the Science Working Group in August 2004. The SWG used the data in this report to make their recommendation of Haleakalā as the preferred site to the NSO Project Director in October 2004. The recommendation was accepted and subsequently endorsed by the Solar Observatory Council (SOC) and the AURA Board of Directors.

Following the selection of Haleakalā as the preferred site for ATST, preparations began on characterizing the site and obtaining the necessary permits for construction. Environmental permitting for Haleakalā requires an Environmental Impact Statement (EIS) as mandated by federal and state statutes. In May 2005, NSO established a contract with Maui-based KC Environmental, Inc. to prepare the EIS. This process began with Notices of Intent and announcements published in the Federal Register.

In July 2005, three formal public scoping meetings were held on Maui to obtain community input on the issues that should be addressed in the EIS. The EIS process is planned to conclude with a Record of Decision by mid 2008. A number of informal meetings with concerned members of the public have been held to offer further opportunity for public input since the July 2005 scoping meetings.



**Figure 1.1-3.** *Renderings of the ATST at the proposed primary (left) and alternate (right) sites on Haleakalā.*

In addition, a series of meetings to support the requirements of Section 106 of the National Historic Preservation Act (NHPA) have been held. Participants in the meetings included the project team, NSF, Native Hawaiians, and other interested parties. An initial informal meeting was held on Maui in January 2006, followed by two formal consultation meetings held in March and April 2006. The Draft EIS document was released for public review and comment in September 2006. The Final EIS document is currently being prepared.

### ***1.1.5 Plans***

During 2009, it is anticipated that the ATST project will transition from design to construction phase. In the near-term, preliminary design efforts, site infrastructure and EIS process, and review of the construction proposal will be the principal project planning activities. Near-term design efforts are concentrating on refinement of the thermal control design for the enclosure, detailed optical feeds to instruments, more complete instrument concepts, Nasmyth instrument and feed concepts, system error budgeting, and performance modeling using the latest Haleakalā site data. Risk management analysis continues and is being fed back into the project budgets (e.g., contingency), schedules (e.g., schedule contingency) and planning (e.g., in-process spares, integration, testing, and commissioning (IT&C) planning and staffing).

### ***1.1.6 Project Planning***

The engineer responsible for each WBS has developed detailed plans, including schedules and budgets, for the construction phase. The systems engineering team and project manager have integrated these details into the overall project schedule. Emphasis will be on near-term planning, but longer-term plans through the construction phase are essential for keeping the end-project goals in mind.

During the D&D phase, detailed plans were initiated for transitioning to operations that will enable life-cycle planning during the design process and help prepare the NSO for the operational phase of ATST.



### ***1.1.7 Construction Phase***

Current planning, based on an FY 2009 construction start, has calendar year 2015 targeted for obtaining the first scientific data with an ATST instrument. Early procurement of the primary mirror by a partner organization has the potential of moving this milestone forward, depending on how early the blank can be purchased and polishing started. To maintain the overall schedule, the construction funding must begin in FY 2009. During the first two years of construction, immediate site work, as well as manufacture of the primary mirror blank and completion of the final fabrication designs will be crucial. Construction of main components such as the enclosure and telescope structure should also be well underway. There will be a year-for-year slip in this schedule if the start of construction funding is delayed further.

### ***1.1.8 Funding***

In FY 2009, adequate construction funding is needed in order to transition the project team from D&D to the construction phase, and to establish commitments on many of the major subcontracts. The project team will transition fully from D&D funding to construction funding when the latter becomes available. This is anticipated to occur in mid FY 2009. The construction funding requirements are based on the budget described in the original construction proposal and as revised following recommendations of the NSF-conducted Cost Review in March 2005 and the Preliminary Design Review Committee in October 2006.

The 2005 cost review resulted in the identification of six main areas that affect the construction proposal budget: 1) delayed start; 2) consequences of site selection; 3) preliminary design effort; 4) specific NSF Cost Review Panel recommendations (e.g., in-process spares); 5) MREFC requirements; and 6) commodity cost increases.

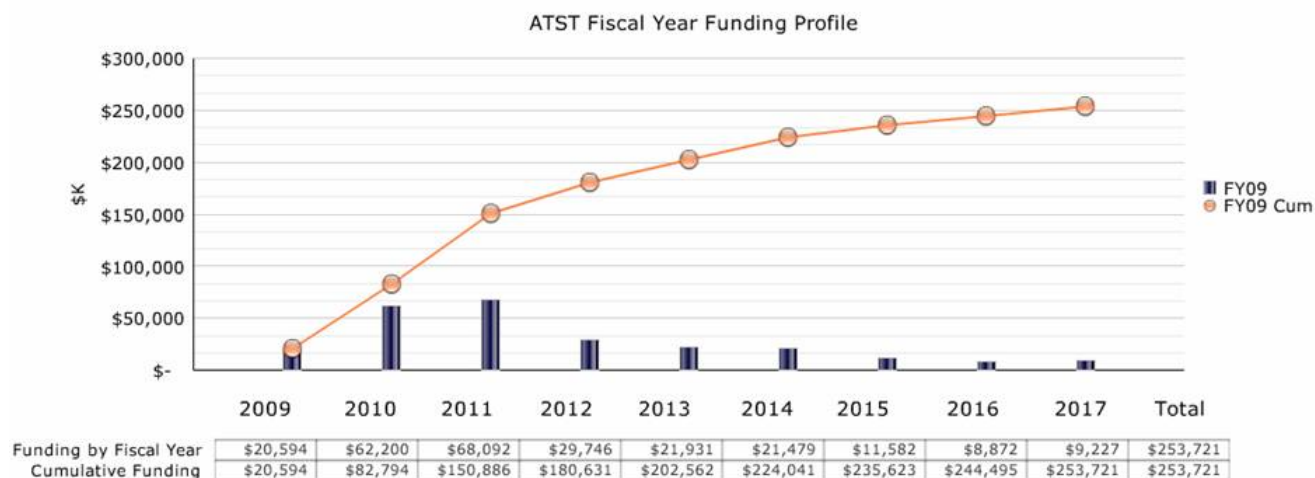
Based on the panel's recommendations, the costs associated with each of these six areas were reviewed and the cost estimates revised accordingly. During the re-costing exercise, the project team reassessed each WBS element in detail. After all elements were examined and re-costed individually, the team reviewed the overall distribution of costs and contingencies to further balance the program and maintain the overall contingency as recommended by the review panel.

The PDR committee's recommendations resulted in a few revised costs as well. The largest change was associated with the factors used to address inflation. These factors were revised according to recommendations from the committee and guidance from the NSF. The latest Office of Management and Budget (OMB) factors for construction were applied to the construction project and the cost estimates were revised accordingly. The other major change resulted from separate NSF guidance regarding the funding profile and the limited funds potentially available for starting the project. The funding profiles proposed in the construction proposal, cost review, and PDR were based on technically driven schedules. The current revised profile is now limited by potential available funding, and therefore the overall schedule has been extended, resulting in increased overall cost.

The estimate of required funds is given in Table 1.1-3, assuming no advanced purchase of the primary mirror. Inflation and an overall 24% contingency on base costs are included. Figure 1.1-4 shows the time-phased funding profile for construction.

**Table 1.1-3. ATST Construction Funding Profile by Level 3 of WBS (Dollars in Thousands)**

	Fiscal Year	2009	2010	2011	2012	2013	2014	2015	2016	2017	Grand Total
1.2.1	Project Management	1,395	4,120	7,823	5,830	6,980	6,654	2,978	2,712	9,000	47,492
1.2.2	Systems Engineering	422	437	452	468	484	501	519	403	0	3,686
1.2.3	Telescope Systems	17,632	55,565	57,782	21,982	11,661	9,075	1,729	1,315	0	176,741
1.2.4	Systems Integration & Testing	0	0	0	0	1,376	3,678	5,010	3,431	0	13,495
1.2.5	Science Support	203	210	217	337	349	391	405	338	0	2,449
1.2.8	Support Services	942	1,868	1,818	1,129	1,082	1,179	942	673	227	9,859
	<b>TOTAL</b>	<b>20,594</b>	<b>62,200</b>	<b>68,092</b>	<b>29,746</b>	<b>21,931</b>	<b>21,479</b>	<b>11,582</b>	<b>8,872</b>	<b>9,227</b>	<b>253,721</b>

**Figure 1.1-4. ATST Construction Funding Profile.**

### 1.1.9 Budget for Design and Development (D&D) Phase Completion

To maintain the project team, support the on-going EIS process, instrumentation development at partner institutions, and perform recommended risk mitigation studies with industry, NSO has requested additional funding to the projected ATST FY 2008 budget. Because of unforeseen additional EIS work and the need for more industrial interaction, the project had a shortfall of approximately \$800K in FY 2007. NSO managed to provide about \$400K by diverting funds from the Director's reserve and other projects. The remaining shortfall resulted in staff reductions, and limited the support of the EIS process. The extent of the project's interactions with industry was also impacted. Recovering this \$400K shortfall in FY 2008, plus an additional \$900K required to fund PDR and SDR review committee recommended risk reduction prototyping and design feasibility and cost analysis studies, along with the \$3M currently budgeted for FY 2008, will permit timely completion of the EIS on Maui, as well as re-staffing and retention of the full engineering team needed to bring the ATST design to final systems design review and readiness for construction. See Section V-3.3.1 for further discussion of required additional risk reduction funding. The shortfall recovery and additional funding will permit implementation of critical risk reduction contracts with vendors. Some of the risk-reduction efforts include M1 assembly design modeling (thermal, actuators), feed optics design modeling, optical system alignment procedure development, AO deformable mirror prototyping and fast tip/tilt



modeling, development of the control system algorithm for wavefront correction, wavefront sensor camera development, enclosure design modeling, and foundation design. These risk reduction efforts with industry flow directly from recommendations made by design and cost review committees.

We continue to support the environmental impact statement process for the Haleakalā site, which has required additional petrel monitoring and NHPA Section 106 efforts at an additional cost of approximately \$400K. Note that the cost of the EIS process is severely limiting the number and scope of the risk mitigation studies and prototyping that the project can initiate in-house and pursue with industry. Providing the requested \$1.3M and the full \$3M requested for FY 2008 are critical to addressing this shortfall and restoring the funding required to meet the recommendations of the design and cost review committees.

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

## 1.2 Adaptive Optics (AO)

With the completion and deployment of the high-order AO systems at the Dunn Solar Telescope and at Big Bear Solar Observatory (BBSO), the technical efforts of the AO project are now focused on the development of multi-conjugate adaptive optics and an advanced AO system for the ATST. The Sun is an ideal object for the development of MCAO since solar structure provides the “multiple guide stars” needed to determine the wavefront information in different parts of the field of view. During FY 2005, a successful MCAO engineering run was performed at the DST. Different algorithms for controlling the two deformable mirrors were tested and one of the deformable mirrors was tuned through different conjugate heights in the atmosphere. The system demonstrated its capability to deliver an extended corrected field. The results were reported at the SPIE meeting in Orlando, Florida in October 2006. However, much of the MCAO development work remains to be done. The major challenge is to develop and implement efficient and stable control algorithms and find optimum and practical positions for the deformable mirrors. More wavefront sensor subfields may also have to be added. The solar MCAO experience will be very valuable to the entire astronomical community. The NSO's main goal, however, is to develop MCAO technology for the ATST. Due to higher ATST and DST project priorities, MCAO the development at the DST at this point remains idle. NSO has attracted a recent graduate from the Kiepenheuer Institute for Solar Physics (KIS) in Freiburg, Germany who resumed the MCAO development work with T. Rimmele starting in January 2007. NSO will continue to pursue a close collaboration with KIS on MCAO development.

## 2 Instrumentation Program

### 2.1 Dunn Solar Telescope (DST)

An aggressive instrumentation program at the Dunn Solar Telescope facility, focusing on exploiting diffraction-limited solar polarimetry, spectroscopy, and imaging, continues into 2008. The program is carried out in strong collaboration with both national and international groups, thus using NSF-funded resources to leverage a much broader base of support. Currently scheduled instrumentation efforts include:

- ♦ Diffraction-Limited Spectro-Polarimeter (DLSP) online data reduction, in collaboration with the High Altitude Observatory (HAO).
- ♦ Spectro-Polarimeter for Infrared and Optical Regions (SPINOR), in collaboration with HAO.
- ♦ Facility Infrared Spectro-Polarimeter (FIRS), in collaboration with the Institute for Astronomy, University of Hawai'i.
- ♦ Rapid Oscillations in the Solar Atmosphere (ROSA), in collaboration with Queen's University Belfast, Ireland.
- ♦ Critical Hardware Upgrade (CHU) of the DST control system.
- ♦ An upgrade to the DST Storage Area Network (SAN).

#### 2.1.1 *Diffraction-Limited Spectro-Polarimeter (DLSP)*

The Diffraction-Limited Spectro-Polarimeter is now operating as a user instrument. In addition to the DLSP, a 1 Å K-line imaging device, a high-speed 2K × 2K G-band imager with speckle reconstruction capability, and a slit-jaw imager, are integrated with the DLSP and high-order AO as permanent capabilities. An “online data reduction tool” effort will begin as soon as possible. As was the case for the DLSP development, this will be done in close collaboration with the High Altitude Observatory. The raw data from the DLSP will be calibrated and a Stokes inversion will be performed on the fly. NSO also plans to make the reduced data available via the Virtual Solar Observatory.

The DST observing staff has recently performed several drills to test the readiness of the DLSP for queue observations. Queue observing is being implemented to take advantage of ideal observing conditions during periods of maintenance, engineering development, and setup time for scheduled observing runs. The queue model is also being developed and evaluated as a scheduling option 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. The ASP wavelength range, however, is restricted to the visible, limiting its ability to sample new solar diagnostics, and its hardware is becoming out-dated and difficult to maintain. 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

control equipment. Software control of SPINOR will be integrated into the DST camera control and data handling systems as opposed to the stand-alone ASP system.

SPINOR will be the primary DST instrument for joint observations with Hinode and 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.

The ASP has been decommissioned and NSO is currently integrating several major sections of SPINOR into the DST. HAO participation has been less than expected due to higher priority projects. However, the HAO Instrumentation Advisory Committee recently decided to grant SPINOR the status of “absolute top priority” starting in calendar year 2008.

### *2.1.3 Facility Infrared Spectropolarimeter (FIRS)*

This is a collaborative project between NSO and the University of Hawai‘i Institute for Astronomy (IfA) to provide a facility-class instrument for infrared spectropolarimetry at the Dunn Solar Telescope. H. Lin (IfA) is the principal investigator of this NSF/Major Research Instrumentation (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. A diffraction-limited, achromatic-reflecting Littrow spectrograph allows for diverse wavelength coverage. A unique feature of FIRS is the multiple-slit design, which allows high-cadence, large FOV scans (four times faster than SPINOR and DLSP) and is a vital feature for studying dynamic solar phenomena such as flares. The high-order Echelle grating allows for simultaneous multi-wavelength observations and thus 3D vector polarimetry. The detector is a  $1K \times 1K$  IR camera synced to a liquid-crystal modulator. The project is currently conducting engineering runs. The NSO is contributing mechanical design work and manufacturing, and assisting with electronic and software design.

### *2.1.4 Rapid Oscillations in the Solar Atmosphere (ROSA) Imaging System*

ROSA is a joint program between NSO and Queen’s University Belfast (QUB). ROSA is a synchronized, multi-camera, high-cadence, ground-based solar imaging system. QUB has established a contract with Andor Corp. for a turnkey camera system. The system includes six high-speed cameras, synchronization electronics, main server, low-level software, GUI, SCSI, RAID, and LTO3 drives. The science that will be accomplished with ROSA include:

- ♦ Photosphere and chromosphere as one coupled system.
- ♦ Waves (200 km – 2000 km) – Mode coupling.
- ♦ Flares –  $H\alpha$  diagnostics of electron beams (timescales 0.1 second).
- ♦ Radiative hydrodynamics of flares.
- ♦ Magnetic field changes at high cadence.

ROSA is expected to arrive at the Dunn Solar Telescope in the summer of 2008 and will be available as a user instrument to the solar community.

### ***2.1.5 DST Critical Hardware Upgrade***

Given the finite time frame for DST operations, replacement and upgrades of hardware and software are limited to the necessary minimum. The critical hardware upgrade (CHU) is aimed at reducing unscheduled downtime by replacing obsolete and unreliable hardware, such as the vintage 1970s CAMAC, with modern hardware. Critical hardware is defined as follows: hardware elements that fail repeatedly, and/or hardware elements that cannot be repaired or replaced without significant downtime or re-engineering. Significant downtime (total) is defined as more than two weeks per year. These upgrades will be limited to supporting existing capabilities rather than offering enhanced capabilities.

### ***2.1.6 DST Storage Area Network Upgrade***

The high data volumes produced by existing and new instrumentation such as IBIS, SPINOR, FIRS, and ROSA, require an expansion in data storage and handling capabilities at the Dunn Solar Telescope. The DST is currently near the maximum capacity of its data handling system (0.5 TB). The IBIS camera upgrade alone will include the integration of IBIS into the DST data handling system and push storage requirements and bandwidth well beyond current capacity. Furthermore, the standard storage media, which is used to transfer data to users, is digital linear tape (DLT). The DST DLT drives are obsolete, downtime is increasing, and DST users have expressed a strong preference for using hard drives as storage media. Hence, the data handling system will be expanded to 4 TB of storage and the existing DLT storage media replaced with removable hard drives.

## **2.2 McMath-Pierce Solar Telescope (McMP)**

### ***2.2.1 NSO Array Camera (NAC)***

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

In 2007, the NAC instrument obtained science data at several wavelengths from 1200 nm through 4666 nm. The NAC is now available to the solar community as a facility instrument at the McMP and is in high demand for solar infrared studies. Instrumental development included completion of the full Stokes polarimeter and observations at 1565 nm of Stokes IQUV profiles of a sunspot, reduction of fringes with a new wedged CaF window, and the establishment of instrument setups for both nighttime and solar direct imaging on the NAC.

The next step for the NAC system is to investigate and develop solar polarimetry in the 3000-5000 nm wavelength region. There are several promising spectral lines in this region that will produce the most sensitive magnetic diagnostics of the solar photosphere, chromosphere and corona. The NAC, in combination with the McMP (which provides the largest IR flux of any solar telescope currently available), will provide a unique opportunity to study these new lines. A first attempt to purchase polarization analysis optics for this wavelength range was unsuccessful, and now vendors are being sought in conjunction with

NASA investigators. 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 an abundance of internal space available, and can accommodate upgrades for use with the ATST first-light instrumentation. The scientific discoveries that will come from the NAC observing runs during the next few years will drive near-infrared science programs at the ATST.

### *2.2.2 McMath-Pierce Telescope Control System (TCS)*

A new telescope control system is desirable to ensure that the McMath-Pierce facility remains competitive and maintainable. A detailed technical request for quote (RFQ) was written and distributed to vendors for bids in 2007. Unfortunately, the quotes received for the project were significantly above what had been budgeted, resulting in the need for a new approach. Lower cost options are being investigated. One possibility is to use commercially available software running on a modern PC to emulate the antiquated PDP-11 control computer. This will address the issue of maintainability of the telescope control computer but will do nothing to enhance the current functionality of the telescope control.

To augment pointing accuracy of the telescope, the NSO is investigating the design of a new guider system for the McMath-Pierce. The new guider will permit precision pointing and tracking of features on and above the solar disk. The current concept utilizes a limb-tracking system mounted above the spectrograph on a computer-controlled, 2-axis translation stage. Four limb sensors mounted at 90° intervals will feed limb-position information to a control computer. The telescope's field of view is sufficient such that at least two of the limb sensors are illuminated when imaging any part of the solar disk. The guider-control computer will analyze the sensors, apply the necessary coordinate rotation between telescope coordinates and spectrographic (guider) rotation and send guide corrections to the telescope. The control computer will communicate with the NAC to synchronize movements of the translations stage to enable 2-D scanning of the solar surface.

### *2.2.3 Image Improvements at the McMath-Pierce*

#### *2.2.3.1 Seeing Improvement*

Tests of potential improvements to the telescope seeing have been conducted during the last several years, including fans blowing air across the McMath-Pierce image-forming (#2) mirror. The #2 mirror is heated by the incoming sunlight, which heats the air layer directly above. This hot layer of air can rise convectively across the solar beam and distort the final image. It is believed that installing fans to flush ambient temperature air across the #2 mirror will diminish or eliminate this contribution to the telescope seeing. Preliminary air flushing tests have been conducted with the McMath-Pierce main and 0.9-m West Auxiliary telescope. Knife-edge images show blowing air across the #2 mirrors clearly affects this seeing layer. The tests demonstrated a need for greater flow volume. Further tests have been scheduled, with full implementation on the main telescope as resources allow.

The wavefront sensor in the adaptive optics system has also revealed other sources of telescope seeing, such as the interface between the telescope and the observing room. Appropriate changes have been made to improve these sources of internal seeing. New tests of the atmospheric seeing will be made from the McMP using a Seykora seeing monitor from Sac Peak, and a project to develop a higher order adaptive optics system for the McMP by collaborators at California State University-Northridge is being proposed to the NSF.

### 2.2.3.2 Adaptive Optics

The infrared adaptive optics (AO) system at the McMath-Pierce Solar Telescope is now in routine use for scientific observations at the main spectrograph. The optical bench configuration has proven to be extremely flexible and has been used to feed the corrected beam to 2-D IR imagers as well as to the spectrograph's input slit. Spectral imaging is achieved by scanning the AO output beam splitter using a stepper-motor-controlled translation stage. This moves the corrected image plane across the spectrograph slit. Most infrared observing runs now routinely request the adaptive optics system. The system can be used with any high-contrast feature smaller than the wavefront analysis camera's sub-aperture field of  $\sim 20$  arcseconds. The AO has a special 1D correction mode for solar limb observations. A commercial, 37-actuator deformable mirror is used for wavefront correction, while image motion is canceled by a high-speed, two-axis, piezo-electric tip-tilt mirror. The system also allows tip-tilt errors to be sent to the telescope for auto-guiding corrections. The autoguide function has proven to be especially useful for tracking objects transiting across the solar disk, such as sunspots.

As currently visualized, the limb guider (see Section II-2.2.2 above) will need to be placed on the optical table situated above the main spectrograph which is the current location of the telescope's infrared adaptive optics system. The new guider will require that the AO bench be relocated below the optical table. Mounting below the optical table will require reconfiguring the AO layout from a vertical to horizontal bench. This is a very low-risk project, as far as the operation of the AO system is concerned, as it simply reconfigures the optical mountings but does not affect the optical design. The final design, programming, construction and implementation of the guider, along with the reconfiguring and relocation of the AO bench, are planned for 2008.

Fully AO-corrected observations of Mercury and other solar system objects are of high interest to future US and European space missions. The current AO bench has been successfully locked onto the planet Mercury and to stars down to magnitude 2.6. This demonstration led to the successful funding of a NASA proposal for the construction of another AO bench to be built at the McMath-Pierce but optimized for Mercury observations. The new planetary AO bench optical design is currently being refined and most of the components have been purchased. Initial testing and the first science results are expected in 2008. As much as possible, the Mercury AO has been designed around components identical to those used on the McMath-Pierce infrared adaptive optics system. This minimizes the necessary design and software effort. It also minimizes the need for stocking and storing costly spare components. Full documentation, including the source code for all of the software, is available on the Web.

The predecessor to the full AO system is an image stabilizer based on the same high-speed piezoelectric tip-tilt correction mirror and wavefront camera used on the AO bench. The image stabilizer is still in high demand for planetary and 12-micron solar observations. Seeing at 12 microns is typically lower than the diffraction limit of the McMath-Pierce, making full AO unnecessary. Increasing the integration time on the wavefront camera now allows image stabilized IR observations of Saturn. With the incorporation of an image intensifier, the image stabilizer has been successfully demonstrated on objects down to 7th magnitude. A duplicate of the tip-tilt correction mirror was purchased by NASA/GSFC and incorporated into the transfer optics of the 12-micron cryogenic spectrometer, CELESTE, for use at the McMath-Pierce. The CELESTE image stabilizer still relies on the use of the NSO wavefront camera and computer.

### *2.2.4 Integral Field Unit (IFU) for the McMath-Pierce*

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

The IFU will be a facility instrument at the McMath-Pierce Solar Telescope on Kitt Peak. The future 4-m-aperture ATST will also require IFUs for its suite of instruments. Thus, this effort is the first step in developing IFUs for the ATST. The IFU assembly is scheduled to be shipped to Kitt Peak for testing at the telescope in late 2007 or early 2008. It should then become available for routine use as a facility instrument at the McMath-Pierce in 2008.

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

#### 1 NSO Telescope Operations

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

##### 1.1 Flagship Facilities

###### 1.1.1 *Dunn Solar Telescope (DST)*

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

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

NSO users and staff are vigorously pursuing the opportunity presented by high-resolution, diffraction-limited imaging at the DST. This work continues to help refine ATST science objectives and requirements, and ensures the growth of the expertise needed to fully exploit ATST capabilities. Proposal pressure on the DST continues to increase as new instruments are interfaced with the AO light feeds. Major science themes that this work will address include:

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



- ◆ Origins of solar variability and atmospheric heating. Role of small-scale flux tubes, convection, and waves.
- ◆ Surface and atmospheric structure. Fields and flows in magnetic structures such as sunspots, pores, filaments, and prominences.
- ◆ Collaborative observations with Hinode. Achieving the science goals of the Hinode mission will require simultaneous ground-based observations. DLSP data will help calibrate and interpret data from the Hinode/Solar Optical Telescope (SOT). Used together, the DST and Hinode should provide unparalleled observations of solar magnetism.

The currently supported instruments are listed in Table III-1. The new instruments being developed, most in collaboration with partners, are described in Section II-2 on Instrumentation.

### *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 1.6-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 $\mu$ 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 remain among the largest solar telescopes (both with 0.9-m diameter and 0.8-m clear aperture) and share the same all-reflective, unobstructed design of the main telescope. The McMath-Pierce facility is scheduled for observing for more hours than any other large NOAO telescope on Kitt Peak because it used both day and night.

The low-cost AO system for diffraction-limited imaging in the IR is now in operation. A large-format 1024  $\times$  1024 NSO array camera (NAC) system, as described in pages 14 and 15, saw first light at the McMath-Pierce in July 2005 and became available to the solar community as a facility instrument at the McMP in 2006.

The instruments available at the McMP are listed in Table III-1 and new instruments are discussed in Section II-2.

The McMP will continue to produce vigorous new work in forefront themes in infrared solar physics, including:

- ◆ The “dark matter” of solar magnetism; sub-kilogauss magnetic fields in the photosphere.
- ◆ The origin of chromospheres; the complex and unexpected structure of the transition between photosphere and chromosphere as revealed by the precise thermometer of the carbon monoxide molecule.
- ◆ The magnetic field in the solar corona; measured with the near-infrared line pair Fe XIII 1074.7/1079.8 nm and potentially with the newly discovered Si IX line at 3932 nm.
- ◆ Discovery; Much of the infrared spectrum is still barely explored, especially in flares, sunspots, and the corona. The polarimetry of the solar spectrum from 3000 to 5000 nm has not yet been studied.

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

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

The SOLIS project records optical measurements of processes within the solar photosphere and chromosphere, the study of which requires well-calibrated, sustained observations over a long time period (25 years). The primary and unique SOLIS instrument is the vector spectromagnetograph (VSM), which was installed on Kitt Peak in April 2004, after seven months of preliminary observing at a temporary site in Tucson. Regular observations from Kitt Peak have been underway since May 2004, with several data products being rapidly made available on the Internet. Researchers have reported excellent results from using high-quality VSM data. The other two SOLIS instruments are an integrated sunlight spectrometer (ISS) and a full-disk patrol (FDP) imager. The ISS has been optically tuned and calibrated, and has been operating daily on Kitt Peak since December 2006. Both the VSM and ISS are in extended commissioning phases, produce good data, and are making regular observations that are available to the community via the Internet. They are gradually reaching their full potentials for providing unique science results. The emphasis in the SOLIS program is on moderate to large spatial scale activity over the course of the solar activity cycle. Other facilities deal more effectively with small spatial scales and short observing campaigns. This emphasis on regular cadence observations for long sustained periods defines the most productive science goals for SOLIS. The FDP was purposely given low priority, due to resource constraints and its non-uniqueness, and is now being completed in Tucson prior to its move to Kitt Peak early in FY 2009.

The primary goal for the SOLIS project has been the completion and stable operation of SOLIS. Data reduction efforts have emphasized the regular production of high-quality vector magnetograms with full-disk and area-scan vector magnetic field observations being archived since September 2003. SOLIS VSM observations have shown a wealth of interesting new phenomena and should lead to many research publications, once the scientific staff has completed initial deployment and data reduction tasks. The VSM Vector Working Group (VSWG) has continued to make good progress with the final calibration and pipeline code for processing VSM 630.2 nm vector data. Currently, the primary task is to better parameterize and remove polarization fringes from the VSM Stokes profile data. During this interim period, quick-look vector magnetic FITS-formatted data and JPEG image files are available for recent observations. The VSM quick-look vector data are also available in x3d format such that the data can be explored as a 3D model. All of the VSM quick-look data are corrected for the 180° ambiguity using the Non-Potential Field Calculation (NPFC) method developed by Manolis Georgoulis (Johns Hopkins U.).

Once all of the SOLIS instruments are completed and consistently producing 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 more complete coverage of transient solar activity. Some efforts will be spent in FY 2008 to pave the way for a SOLIS VSM network.

#### *1.1.4 Global Oscillation Network Group (GONG)*

The Global Oscillation Network Group is an international, community-based program to monitor the internal structure and dynamics of the Sun using helioseismology, as well as the surface magnetic field. GONG operates a six-station network of automated and extremely sensitive and stable solar velocity, intensity, and magnetic imagers located around the Earth. The network ensures that at least two sites can see the Sun at all times, minimizing data loss due to bad weather or technical problems and effectively providing continuous observations. A set of  $1024 \times 1024$  pixel images is obtained every minute at each of the sites. Once a week the data are shipped to project headquarters, where the data from all six sites are calibrated and merged. Scientific products include normal mode frequencies for studying the global internal structure; maps of the internal dynamics from local helioseismology; images of the far side activity, and high-cadence surface magnetic field images.

In addition to the operation of the instruments and data acquisition network, GONG operates a data reduction and analysis system to process the observations and facilitate activities of the scientific community. Properties of the global  $p$ -modes have been used to track the evolution of the interior through solar cycle 23, and now the first record of changes in the solar convection zone over a complete activity cycle is available. The GONG++ data processing pipeline system focuses on local helioseismology methods—tracking and remapping ring diagrams, time distance, and holography—to probe the inhomogeneous and intermittent structure below the surface. GONG is now continuously calculating near-real-time farside maps of the back of the Sun using helioseismic holography.

In addition, GONG provides photospheric line-of-sight magnetograms and intensity images in the 6768 Å Ni line. These magnetograms are obtained every minute around the clock, and provide a unique and unprecedented record of the solar magnetic field. A ten-minute average magnetic field image is returned in near-real time from each of the sites, and these are combined into a synoptic map on an hourly basis. GONG also produces a potential field source surface extrapolation of the magnetic field in the solar corona every hour. The GONG magnetic-field products are now acknowledged to be the best available by the solar physics research community.

GONG results to date have substantially advanced solar astronomers' knowledge of the Sun's structure and dynamics, and have tested fundamental theories of physics and astrophysics. Significant structural and dynamic variations with the sunspot cycle, such as the evolution of the torsional oscillations, the cyclic spin-up and slow-down of the polar rotation, and possible variations in the rotation rate in the tachocline at the base of the convection zone have now been observed. The ring-diagram method has revealed the presence of a distinctive flow pattern below active regions that produce many strong flares, and the temporal variation of this flow may be able to predict the occurrence of a flare. The farside signal has been calibrated in terms of the magnetic field, providing better constraints for synoptic maps of the surface magnetic field.

NSO will continue to operate the GONG network of instruments to monitor the systematic variations in the structure and dynamics of the solar interior with magnetic activity, and to provide continual observations of

the surface magnetic field. GONG will continue to pursue opportunities, advancing the major topics in helioseismology and solar physics, including:

- ◆ High-resolution, high-cadence magnetograms. Continuous, high signal-to-noise ratio, high temporal-resolution magnetograms are of broad interest for field extrapolation science and evolution studies, and extend the SOLIS data by providing a continuous temporal context.
- ◆ Local helioseismology, to probe the inhomogeneous and intermittent structures below the surface (tracking and remapping for ring diagram, travel time, and acoustical holography analysis).
- ◆ Farside imaging. Near real-time images of the far side of the Sun 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 forecasters.
- ◆ 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.

## 1.2 Synoptic Facilities

### 1.2.1 *Evans Solar Facility (ESF)*

The US Air Force currently provides support for the ESF to continue their synoptic coronal emission line program. Other users are given access to the facility if they can provide their own support. Currently, the High Altitude Observatory would like to use the facility for some experiments in coronal magnetometry and has reached an agreement with NSO and the AF program. Preliminary observations with the system are planned for the spring of 2008.

### 1.2.2 *Hilltop Solar Facility*

The Hilltop also houses a coelostat that feeds an optical bench currently used for testing narrow-band filter systems and other instruments. NSO plans to develop part of the ATST AO system using this bench. After demonstrating coronal magnetic field and wave measurements, the High Altitude Observatory will move the coronal one-shot and its instrumentation to Haleakalā, where it will be used to make coronal vector magnetic field measurements in campaign mode. Haleakalā generally has the best coronal skies, as shown in the ATST site survey report. The telescope will be placed on the Mees spar and will support a collaboration between NSO, HAO and the University of Hawai‘i.

## 2 Digital Library and Virtual Solar Observatory (VSO)

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic data sets over the Internet to the research community. Since the inception of the Digital Library in May 1998, more than 7.3 million science data files have been distributed to about 8,000 unique computers. These figures exclude any NSO or NOAO staff members.

Today’s Internet is the key enabler of alternate modes of observing and data delivery. It provides direct

interaction between astronomers at remote locations with on-site observers, and allows rapid data dissemination. Perhaps most importantly, the Internet leverages the scientific return on the investment in the facilities by providing access to data archives. These archives can produce new scientific results well after the original data sets are obtained.

NSO has continued to improve its server for Web pages and data archives. This server currently has 20 Terabytes of disk space, and will eventually be equipped with 24-30 Terabytes of on-line disc storage. This is sufficient to hold about seven years of reduced 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 SOLIS magnetograms.

In order to further leverage the substantial national investment in solar physics, NSO is participating in the development of the Virtual Solar Observatory (VSO). The VSO provides a unified gateway to distributed solar data archives with access through the WWW. The system has been accessed approximately 60,000 times since Version 1.0 was released in December 2004. The current version, 1.4, provides access to 65 major solar data sets along with a shopping cart mechanism for users to store and retrieve their search results.

The overarching VSO goal is to facilitate correlative solar physics studies using disparate and distributed data sets. 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 2008**

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

<b>Instrument</b>	<b>Telescope</b>	<b>Comments/Description</b>
<b>NSO/Sacramento Peak – OPTICAL IMAGING &amp; SPECTROSCOPY</b>		
High-Order Adaptive Optics	DST	60 - 70-mode correction
Interferometric Bidimensional Spectrometer (IBIS)	DST	Spectroscopy – Polarimetry, 20 mÅ resolution, 617 nm – 854 nm
Diffraction-Limited Spectro-Polarimeter	DST	6302 Å polarimetry, 0.1 arcsec and 0.25 arcsec/pixel
Universal Birefringent Filter (UBF)	DST	Tunable narrow-band filter, $R \leq 40,000$ , 4200 - 7000 Å
Horizontal Spectrograph	DST	$R \leq 500,000$ , 300 nm - 2.5 $\mu\text{m}$
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies
Littrow Spectrograph	ESF	$R \leq 1,000,000$ , 300 nm - 2.5 $\mu\text{m}$
Various CCD Cameras	DST	380 - 1083 nm; Formats: 256 × 256 to 2K × 2K
Correlation Tracker	DST	Tip/tilt correction
40-cm Coronagraph	ESF	300 nm – 2.5 $\mu\text{m}$
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å
H $\alpha$ Video	HT	H $\alpha$ full-disk
<b>NSO/Sacramento Peak – IR IMAGING &amp; SPECTROSCOPY</b>		
Horizontal Spectrograph	DST	High-resolution 1- 2.5 $\mu\text{m}$ spectroscopy/polarimetry, $R \leq 300,000$
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 $\mu\text{m}$ spectroscopy/polarimetry
<b>NSO/Kitt Peak – IR IMAGING &amp; SPECTROSCOPY</b>		
SOLIS Vector Spectromagnetograph	KPST	1083 nm: Stokes I, 2000 × 1.1 arcsec, 0.35-sec cadence 630.2 nm: I, Q, U, V, 2000 × 1.1 arcsec, 0.7-sec cadence 630.2 nm: I & V, 2000 × 1.1 arcsec, 0.35-sec cadence 854.2 nm: I & V, 2000 × 1.1 arcsec, 1.2-sec cadence
SOLIS Integrated Sunlight Spectrometer	KPST	380 – 1083 nm, $R = 30,000$ or 300,000
Vertical Spectrograph	McMP	0.32 - 12 $\mu\text{m}$ , $R \leq 10^6$
1-m Fourier Transform Spectrometer (FTS)	McMP	2200 Å to 18 $\mu\text{m}$ , $R \leq 600,000$
NSO Array Camera (NAC)	McMP	1 - 5 $\mu\text{m}$ , 1024 × 1024, direct imaging, and full Stokes polarimetry from 1- 2.2 $\mu\text{m}$
CCD Cameras	McMP	380 - 1083 nm, up to 1024 × 1024 pixel
ZIMPOL I	McMP	450 – 1100 polarimetry, 10 Hz, 300 × 400
IR Adaptive Optics	McMP	2 – 12 $\mu\text{m}$ , shared risk use with vertical spectrograph
Stellar Spectrograph	McMP	380 – 1083 nm, $R \leq 10^5$
Image Stabilizer	McMP	Solar, planetary or stellar use to 7 <sup>th</sup> magnitude for use with the vertical or stellar spectrograph
Wide-Field Imager	McME	Astrometry/Photometry, 6 arcmin field
<b>NSO/GONG – GLOBAL, SIX-SITE, HELIOSEISMOLOGY NETWORK</b>		
Helioseismometer & Magnetograph	California, Hawaii, Australia, India, Spain, Chile	2.8-cm aperture; imaging Fourier tachometer of 676.8 nm Ni I line; 2.5 arcsec pixels; 1-min. cadence.

## IV EDUCATION AND PUBLIC OUTREACH

NSO has a comprehensive public affairs and educational outreach plan that includes graduate research and training, undergraduate research, teacher research and research-to-classroom experiences, public programs, media information, elements of distance (Internet) learning, and K-12 education.

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).

In addition to its own programs described below, 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.

### 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.** NSO actively recruits postdoctoral and research fellows. Most of the funding for these programs comes from externally funded grants and projects that are outside the NSO's operational funding. Currently, NSO has two research fellows supported by the ATST project and two supported by NASA programs including Living with a Star and STEREO. We will be adding another postdoctoral fellow supported by the HINODE program through a contract with Lockheed.

**Thesis Students.** NSO annually hosts one or two students working on advanced degrees. NSO staff members serve as adjunct faculty and act as the local thesis advisors. Jose Marino from NJIT has been in residence at Sunspot and in 2007 completed his PhD in adaptive optics with Thomas Rimmele as his advisor. Lucia Kleint from ETH in Zurich spent several months in Sunspot in 2007 to obtain data for her Master's thesis, and Brian Harker of Utah State University will be completing his thesis in spring 2008 under the supervision of K. S. Balasubramaniam.

**REU/SRA.** The NSO summer research programs remain a very effective tool for introducing students to research in solar physics. A large fraction of active solar astronomers worldwide (as well as science/engineering leaders in other disciplines) have been alumni of the NSO summer programs. 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. Over the past decade, women have comprised 53% of the REUs (56% since 2003) and 38% of the SRAs (41% since 2003), and minorities 11% of the two programs.

**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. 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.

**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.

**Further Undergraduate and Graduate Outreach.** In the summer of 2006 and 2007, NSO and the University of Arizona held a Solar Physics Summer School at Sunspot for about 100 undergraduate and graduate students (and a few faculty wanting to expand their experience base). This will be repeated in 2008.

**New Programs.** In fall 2006, NSO started developing contacts with educators on Maui in anticipation of building the ATST at Haleakalā. NSO is combining existing EPO initiatives, under development since 2005, and proposing them to the NSF Informal Science Education (ISE) program in 2008. These initiatives are: *Magnetic Carpet Ride* (formerly Max 2008), *The Goldilocks Star* (formerly Other Suns for Other Worlds), and *Sizing Up Your Solar System*. These will be designed to complement TLRBSE and Project ASTRO as well as outreach to schools and public programs, and as part of NSO's contribution to the International Year of Astronomy in 2009. *Magnetic Carpet Ride* will take advantage of Cycle 24, which should start rising in 2008, and the centennial of Hale's discovery of solar magnetism (2008). It will develop classroom and temporary museum exhibit activities relating to the magnetic nature of the Sun and building on the "magnetic carpet" metaphor for the fine-scale structure of the solar magnetic field. *The Goldilocks Star* will take the natural interest in nighttime astronomy and the hunt for other planets that support life as a means of teaching about our Sun. This will be a multidisciplinary project, with classroom and museum components, covering aspects of physics and life sciences. Portions of this activity will complement the Kepler Mission, which will search for Earth-like planets. *Sizing Up Your Solar System* is a collection of classrooms exercises to complement the Sunspot Solar System Model that will be built in 2008 with a grant from the New Mexico Tourism Department (significant effort was spent in 2007 in developing the booklet and redesigning the model). *The Sun on Wheels* will be a van equipped with telescopes, lesson plans, and other materials that can take elements of these programs to schools and public events. We hope to use the Digital Bus, a successful industry-government education initiative on Maui, as a prototype of *The Sun on Wheels*. To help establish the need for these activities, the EPO officer will complete the development of public questionnaires (started in 2007) to determine the extent of public understanding about solar magnetism and about habitable stars. A preliminary inquiry at a local high school in early 2005 revealed that a number of students think solar magnetism holds the planets in orbit. One



questionnaire will be a pre/post-visit test focused on the Sunspot Solar System Model (with a possible variant for tourists). The other will be administered in public settings to the public to determine their level of understanding.

## 2 Other Outreach

In late summer 2004, the NSO joined as a co-investigator with the University of Arizona (UofA) Department of Planetary Sciences, Lunar and Planetary Laboratory (LPL) in the submission of a proposal to a new NSF program entitled "Faculty Development in the Space Sciences." This novel program, administered by the 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 space sciences, solar physics and other related fields. The NSO was invited to collaborate in the submission of a proposal for a new faculty position in solar physics at LPL. 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. The proposal was funded and resulted in the recent faculty hiring of Tami Rogers, who has been working on theoretical numerical simulations of solar internal gravity modes, and will be searching for these modes in GONG data.

During FY 2007, the NSO partnered with the UofA/LPL in establishing a new graduate program in solar physics at the UofA. Announcements about this new program were made both formally and informally at various venues, including the AAS/SPD meeting in Hawaii, the NSO Workshop 24 at Sac Peak in April, and the UofA-LPL/NSO Solar Physics School at Sac Peak in June. Opportunities for collaborations with NSO scientific staff were featured in the announcement. Thomas Schad, a former (2006) NSO/REU student, has been admitted to the graduate program at LPL and is the first solar physics graduate student in this new program. His co-advisors are LPL's Joe Giacalone and NSO's Matt Penn.

At the Sunspot Astronomy and Visitor Center, we have completed the live solar viewer that will project a white-light image of the Sun from a heliostat outside the Visitor Center to a screen inside the center. In 2008, NSO will install an 8-inch Meade SCT with a neutral-density solar filter in front of the Visitor Center to enable direct public viewing of the Sun. Two Coronado Personal Solar Telescopes, with H-alpha and Ca II K filters, will be co-mounted. This will help address the most common visitor question, "Is there a telescope where *we* can look at the Sun?" The telescopes will be mounted on a pair of piers to enable access by visitors in wheelchairs. (Delayed from 2007 by other work in the engineering department.) Components of *Magnetic Carpet Ride* will be developed for use in the Visitor Center. It will include a combination of computer stations with interactive graphics, hands-on units, and models of the Sun and of a sunspot. As a pathfinder for this exhibit, NSO will develop classroom activities to teach junior high and high school students about solar magnetism. This will include a combination of hands-on activities for students and demonstrations that would be conducted by teachers or an NSO officer. These activities will evolve into the educational activities and public information that would accompany a museum exhibit. Additional exhibit materials include new display panels for the Dunn Solar Telescope lobby (deferred for work on the National Atomic Museum exhibit) and the Visitor Center to highlight current observing programs at Sunspot. For the International Year of Astronomy, NSO is investigating the development of two types of spectrohelioscopes, based on existing designs. One would allow visitors to "tune" to the Sun in different wavelengths. The other would have higher spectral resolution for student operation online.

NSO has designed a 1:250-million-scale Sunspot Solar System Model for the Sunspot Astronomy and Visitor Center. The scale is set by sizing the model so Neptune passes through the New Mexico Museum of Space

History in Alamogordo, an anticipated partner in the project. This also enables nationwide use of educational materials being designed to complement the model (i.e., the scale does not tie it to one location), including Maui, where placing the Sun at the planned ATST site will have Pluto pass through the city of Kahului. Ultimately, the model will include an 18-foot-diameter walk-through model of the Sun (a first) and scaled models of the planets at the Visitor Center, as well as planet markers along the Sunspot Scenic Byway (NM 6563) stretching to Cloudcroft and Alamogordo. The State of New Mexico has allocated \$75,000 through its capital funding program for the project. This requires a redesign of the model and deferring the interior fitting of the Sun until additional funding is available. Follow-up proposals for the Sun and planet models will be submitted to NSF/ISE and to Scenic Byways in 2008. The model will include four new 6 × 8-ft graphics panels: “Our Sun from the Inside Out” (90% complete in 2007), “Sizing Up Your Solar System” (completed in 2007), “One Star Among Many” (33% complete in 2007), and “A Map of the Universe” (25% complete in 2007). Components of this exhibit were used in a temporary exhibit on the Sun at the National Atomic Museum, in Albuquerque, March–September 2007. A major component of the Sunspot Solar System Model is “Sizing Up Your Solar System,” class exercises for students to build models of sunspots and Earth to the 1:250-million scale, or to scales using inflatable planetarium domes to represent the Sun.

NSO will investigate the potential for building an ATST Visitor Center at an appropriate location on Maui. There are plans to meet with outreach counterparts from the University of Hawaii Institute for Astronomy, Air Force, and other Haleakalā tenants, as well as local cultural and educational representatives, to define interest in a joint visitor center (with shared overhead costs and floor space), perhaps starting as a series of temporary exhibits in rented space.

### 3 Media and Public Information

**Print Products.** An ATST press kit (fact sheet, technical news reference, image collection) started in 2007 will be ready for distribution in early calendar 2008.

**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 2008 include SOLIS operations, the AO/DLSP combination at the Dunn Solar Telescope, the development of SPINOR, and other capabilities at Sunspot and Kitt Peak. Other stories will be based on observing programs at Kitt Peak and Sunspot and of science papers published by the NSO staff.

## V MANAGEMENT AND BUDGET

### 1 NSO Organization

NSO is currently managed in four major functional units, NSO/Sacramento Peak (NSO/SP), NSO/Tucson (NSO/T), NSO/GONG, and NSO/ATST. NSO conducts operations and projects with a combination of positions funded from its base NSF support, 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, and administration) with NOAO in Tucson and on Kitt Peak. Funds for these shared services, except for mountain support of NSO/Kitt Peak facilities by KPNO, are in the NSO budget and are shown on the NSO spending plan. However, these funds are currently committed to NOAO for shared services, which results in considerable cost savings. The NSO Director's office consists of two employees, the Director and an executive assistant, and receives financial and budget support from the NSO/SP facilities manager. The Director currently resides at NSO/SP. The NSO Deputy Director serves as site director for Tucson and oversees operations there, and also serves as the SOLIS PI. His funding is included in the Tucson base budget. In addition, the NSO Director shares support personnel with NOAO for accounting, human resources, graphics, and educational outreach. Funds for the NOAO shared services are in the NSO budget and are shown in the NSO spending plan (Section V-3). Appendix C shows the staffing levels for all but the NOAO positions.

NSO/SP primarily operates the Dunn Solar Telescope on Sacramento Peak as well as offices, computing, instrument development, and housing facilities for visitors and the resident scientific and technical staff. The DST program scientist leads and oversees telescope operations and instrument projects and also serves as ATST project scientist. The DST project and telescope manager reports directly to him. Major projects at NSO/SP include development of adaptive optics and multi-conjugate adaptive optics, development of the DLSP and SPINOR, upgrading the data and control systems at the DST, and work on the ATST design. In addition, NSO/SP conducts experiments and smaller projects to improve near-IR cameras and spectroscopy, narrowband imaging in the visible and IR, and vector polarimetry techniques that can take advantage of high-resolution facilities. Some support is also provided to Air Force- and HAO-funded programs at the Evans Solar Facility and Hilltop Facility, respectively. NSO/SP also has a support facilities and business manager who is responsible for buildings and grounds, administration and business functions. Both the DST program scientist and the support facilities and business manager report to the Director.

NSO/T operates the McMath-Pierce Solar Telescope and SOLIS on Kitt Peak, offices in Tucson, and conducts projects at the Tucson facilities. The deputy director oversees Tucson programs and operations. McMath-Pierce operations and projects are led by a telescope scientist who reports to the deputy director. A project and telescope manager and the SOLIS program scientist also report to the deputy director. NSO shares support personnel with KPNO on Kitt Peak and with the other NOAO divisions in Tucson. Major projects at NSO/T include completing SOLIS instrumentation, large-format IR camera development, and work on the ATST design. NSO/T also conducts experiments and minor projects to improve Stokes polarimetry techniques, imaging at the McMath-Pierce Solar Telescope, solar-stellar observation techniques, and speckle imaging techniques.

NSO/GONG, located in Tucson, operates and maintains the GONG network of six telescopes and collects, processes and provides data to users. GONG is led by a program scientist. A program manager is responsible for daily GONG operations and reports directly to the program scientist.

NSO/ATST is funded primarily by the ATST D&D proposal and planned funding to bridge the period leading up to the start of construction. The ATST staff resides in both Tucson and Sacramento Peak, allowing the team to interact with NSO staff and take advantage of lessons learned from current telescope operations and projects at both sites.

A current high-level organizational chart for NSO is shown in Figure V-1. Detailed charts are shown in Appendix G. As NSO prepares for operations in the ATST era, the management structure will evolve as needed to provide the most efficient and cost effective structure. Once ATST construction funding is secured, NSO will begin reorganizing to support ATST operations. This will lead to the ramp down of current operations and divestments of current facilities as ATST construction reaches completion.

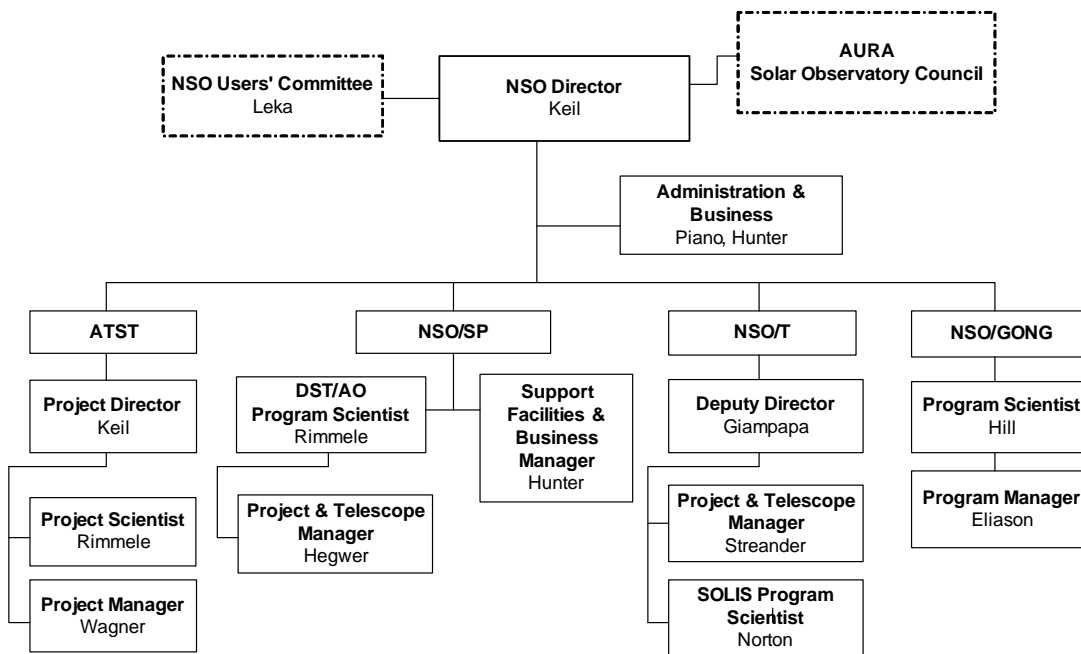


Figure V-1. NSO high-level organizational chart.

In the ATST era, the NSO organizational structure will evolve to effectively support ATST, the synoptic program, an instrument program, and a data processing and distribution center. The exact structure will depend on partner contributions to ATST and synoptic programs.

## 2 Senior Review Actions

Major components of the NSO FY 2008 program relevant to the Senior Review recommendations include:

- ♦ Continued development of the 4-meter Advanced Technology Solar Telescope on behalf of, and in collaboration with, the solar community. NSO will complete the EIS and await NSF's record of decision; prepare materials as needed for the NSF/MPS presentation of ATST to the National Science Board; and prepare for the final MREFC review before the start of ATST construction. NSO will continue to shift resources from

current operations to ATST development in a manner that allows the continuation of support for the solar community with current resources, though at a reduced level.

- ♦ Starting the detailed planning for NSO Headquarters (HQ) location and NSO consolidation. Part of this planning will depend on the NSF ATST record of decision on the EIS for building on Haleakalā. As soon as that is in hand, NSO will negotiate with the University of Hawaii and construction of the ATST remote operations facility will begin. NSO will work with AURA and NSF to draft a plan that incorporates the opportunity for an open competition among Universities and institutions for hosting an NSO HQ facility.
- ♦ Actively seeking partnerships for a multi-station Synoptic Optical Long-term Investigation of the Sun (SOLIS) network. NSO will continue its negotiations with the Algerian solar community. The Algerians have obtained funding for a new solar facility and expressed interest in collaborative development of a SOLIS vector spectromagnetograph (VSM). The Instituto de Astrofísica de Canarias (IAC) and the Kiepenheuer Institute (KIS) have also expressed interest in participating in a network. NSO will seek other partnerships in Asia or Australia to complete a three-station network.
- ♦ Actively seeking external funding for the Global Oscillation Network Group (GONG) telescope operations. NSO will approach the partners that are operating the individual sites about the possibility of assuming the cost of respective site operations. NSO will also work with the data users to obtain additional operating funds.

### 3 FY 2008 Spending Plan

Table V-1 summarizes the NSO budget in FY 2008 for its current program of providing support to the US solar physics community and developing the ATST. Development of the NSO 2008 program is based on receiving \$11,300K for its combined base program (\$8,300K, Tables V-3 through V-9) and the ATST project (\$3,000K, Table V-10). NSO also receives operational support from the Air Force Research Laboratory (AFRL) through a Memorandum of Understanding between the AF and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NSO earns revenue from operation of the cafeteria, the Visitor Center, and housing on Sacramento Peak. In order to avoid a reduction in force in FY 2008, while maintaining a progressive ATST funding line, approximately \$281K of indirect earnings and FY 2007 carryover have been programmed into the revenue line. The remaining revenues are used to support the operations that generated them.

<b>Table V-1. NSO FY 2008 Funding</b>	
<i>(Dollars in Thousands)</i>	
NSF Division of Astronomical Sciences Funding	<b>11,300</b>
AFRL Support for Sac Peak Operations	<b>400</b>
NSF REU/RET Program	<b>119</b>
REVENUE (Housing, Kitchen, Visitor Center)	<b>171</b>
ATST Fellowship Support	<b>150</b>
Programmed Indirects/Carryover	<b>281</b>
<b>Total NSO Funding</b>	<b>\$12,421</b>

In addition to the funds shown in Table V-1, 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 normally made available to the user community. Currently, there are several programs that fall into this category. Funding from the NASA STEREO mission 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 also provides funds to collect high-resolution FTS spectra of the Earth's upper atmosphere, and the NSF Chemistry Division 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, as well as a NASA grant through Lockheed to support the Hinode mission.

The NSO funding shown in Table V-2 is 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 functional area and task. Table V-2 summarizes the planned spending, and Figure V-2 shows the percentage of the programming going to each task area shown in the budget table in Appendix C.

<b>Table V-2. NSO FY 2008 Planned Spending by Functional Area</b>	
<i>(Dollars in Thousands)</i>	
Director's Office <sup>1,2</sup>	385
AURA Corporate Fee	329
Educational & Public Outreach (EPO) <sup>3</sup>	321
Tucson/Kitt Peak <sup>1</sup>	1,764
Sacramento Peak <sup>1</sup>	2,615
GONG <sup>1</sup>	2,916
ATST D&D Effort	2,943
ATST In-House Contribution <sup>4</sup>	768
SOLIS	380
<b>Total NSO Program</b>	<b>\$12,421</b>

<sup>1</sup>Contains programmed indirects and carry over.

<sup>2</sup>Funding for 40% of the NSO director's time and some non-payroll has been moved into the ATST in-house contributions.

<sup>3</sup>Combines the EPO funding at Sac Peak and Tucson, and EPO support received from NOAO.

<sup>4</sup>This number represents in-house personnel working on ATST-related technology, ATST design, and non-payroll support of these efforts not paid out of the ATST account.

The EPO line in Table V-2 does not contain contributed efforts by the scientific staff. Although scientists spend part of their time on EPO activities, their salaries are contained in the Tucson, Sac Peak and GONG budgets.

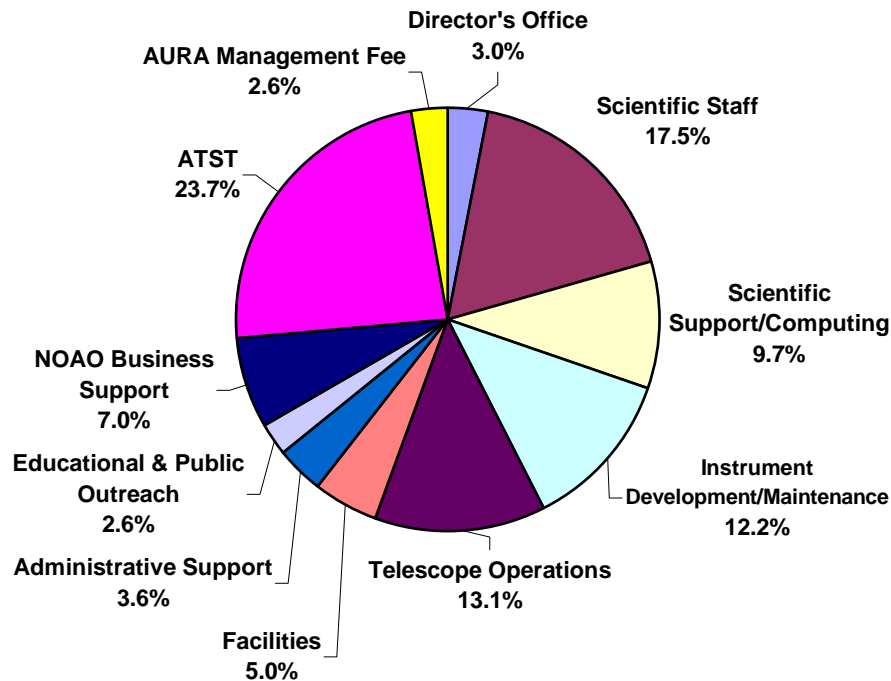


Figure V-2. *Distribution of the NSO FY 2008 budget.*

Tables V-3 to V-9 break out the spending plan for the major functional units in more detail. The funding summarized on the outreach line of Table V-2 that is spent in each location is shown at the end of each table. The outreach support received from NOAO for the programs in Tucson and at Sac Peak is shown in the table for the director's office.

Table V-3 presents the director's office budget. Some of the indirect amounts earned from non-NSF funded projects are budgeted toward 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. To accurately account for NSO support of ATST, \$100K of the salary in the director's office and \$10K of non-payroll have been transferred to the ATST in-house budget shown in Table V-8.

<b>Table V-3. Director's Office</b>			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Staff	245	2	247
Committees	0	12	12
NOAO Support	12	5	17
<b>Total Director's Office</b>	<b>\$257</b>	<b>\$19</b>	<b>\$ 276</b>
Outreach Support from NOAO	78	33	111

Table V-4 shows the budget breakdown for Tucson operations and Table V-5 the support of SOLIS. The Tucson staff provides support for operations on Kitt Peak and the SOLIS project. Most of the instrument development program will be devoted to SOLIS and supporting the NSO Array Camera and telescope pointing upgrade for the McMath-Pierce.

<b>Table V-4. NSO/Tucson</b>			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	412	39	450
Scientific Support/Computing	200	10	210
Instrument Development	121	20	141
NOAO ETS	80	0	80
Telescope Operations	148	77	224
NOAO Support	274	69	343
<b>Total NSO/Tucson</b>	<b>\$1,235</b>	<b>\$215</b>	<b>\$1,448</b>
Outreach (REU/RET)	47	12	59

<b>Table V-5. NSO/SOLIS</b>			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	140	15	155
Telescope Operations	410	130	540
<b>Total NSO/SOLIS</b>	<b>\$550</b>	<b>\$145</b>	<b>\$695</b>

Table V-6 breaks out the Sacramento Peak operations budget. Instrument development is concentrating on MCAO and upgrades to the DST control system, as well as focal-plane instrumentation so users can take full advantage of diffraction-limited imaging. The DST program scientist and project manager oversee telescope operations and projects. The Sac Peak administrative staff oversees site maintenance and daily site operations, visitor support, purchasing, shipping, receiving and budgeting. The facilities budget includes costs for buildings (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.

<b>Table V-6. NSO/Sacramento Peak</b>			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	351	33	384
Scientific Support/Computing	179	115	294
Instrument Development	610	75	685
Telescope Operations	193	26	219
Facilities	256	363	619
Administrative Services	242	24	266
NOAO Support	118	29	147
<b>Total NSO/Sacramento Peak</b>	<b>\$1,949</b>	<b>\$665</b>	<b>\$2,614</b>
Outreach (REU/RET)	106	45	152



Table V-7 contains the \$400K contribution of the US Air Force as well as the revenue earned from housing, meal services, and Visitor Center sales. The USAF funding is added to the general operations funding of NSO to offset the support given to the Air Force Research Laboratory program at Sac Peak. Table V-7 provides an estimate of how AF funds will be used to support the AFRL program. This varies from year to year, based on program needs and facility usage.

<b>Table V-7. Air Force FY 2008 Funding</b>			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Support/Computing	65	39	104
Telescope Operations	25	8	33
Instrument Development	15	5	20
Facilities	87	80	167
Administrative Services	50	26	76
<b>Total Air Force</b>	<b>\$242</b>	<b>\$158</b>	<b>\$400</b>

Table V-8 summarizes the GONG spending plan for FY 2008. 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 V-3). Additional personnel working on GONG are supported on grants from NASA (\$237K) and NRC (\$45K). These funds are not shown in the table.

<b>Table V-8. NSO/GONG</b>			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
Scientific Staff	845	30	875
DMAC Operations	572	127	699
Telescope Operations	476	438	914
Administrative Services	172	10	182
NOAO Support	196	49	245
<b>Total NSO/GONG</b>	<b>\$2,261</b>	<b>\$654</b>	<b>\$2,915</b>

### 3.1 ATST Program

NSO personnel at both NSO sites contribute to the development of the ATST in addition to those personnel directly funded by ATST. This includes programs to continue the development of the next generation of adaptive optics and infrared technologies. Table V-9 summarizes the NSO in-house investment in the ATST. The ATST spending plan for the \$3,000K of new D&D funding is shown in Section II-1.1.9, Table 1.1-3 (page 10).

<b>Table V-9. NSO IN-HOUSE CONTRIBUTION TO ATST</b>			
<i>(Dollars in Thousands)</i>			
	<i>Payroll</i>	<i>Non-Payroll</i>	<i>Total</i>
ATST Director	100	10	110
Science Support	150	10	160
Technical Support	300	40	340
ATST Fellowship	125	25	150
<b>Total ATST In-House Contribution</b>	<b>\$675</b>	<b>\$85</b>	<b>\$760</b>

The proposed design and development phase of the ATST project covered five years, beginning in the last few months of 2001 and ending in early 2006. The original plan was to transition from the D&D phase to a six-year construction phase that was planned for starting in FY 2006. Final designs at some of the vendors were planned for the early construction phase. Current guidance from NSF indicates that the project should plan for a 2009, or perhaps later, start. Thus, the ATST project is requesting additional D&D support to begin some of these final design efforts in FY 2008 and FY 2009, as well as to complete environmental assessment of the recommended ATST site on Haleakalā. The request for additional funding is explained in Section II-1.1.9.

### 3.2 Funding Priorities

NSO is totally committed to developing the ATST. 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 the Advanced Technology Solar Telescope replaces them.

Supporting US solar astronomers to obtain high-resolution observations in the visible and IR is critical if the US 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 NSO currently enjoys 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. NSO/SP is concentrating on AO and telescope technology testing while aggressively seeking partners and funding for these activities. NSO has delayed, or postponed indefinitely, 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. NSO/T is concentrating on IR development and high-resolution imaging and spectroscopy in the infrared.
- ♦ Contribute scientific staff time from both sites to ATST development (AO, IR technology, and design).
- ♦ Operate SOLIS and seek partners to develop a 3-station SOLIS network. Operate the new high-resolution version of GONG for at least one solar cycle. We are seeking outside funding to help maintain GONG operations.

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

### 3.3 Strategic Needs

NSO strategic needs fall into two areas: those needed to advance the ATST project and those to keep current facilities functioning at a level that provides first-rate support to the solar community and provides for a safe working environment. Thus we are requesting additional support above the FY 2008 funding approved in the current budget. Because NSO is the primary provider of ground-based user support and synoptic data for the US community, a smooth transition from current operations into the ATST era is critical to the health of US solar physics.

### 3.3.1 ATST Design Completion

Specific areas where funding enhancements would support ATST strategic needs and thus provide a smooth transition into construction are given in Table V-10. The full ATST budget and budgetary needs are shown in Section II-1.1.9. An enhancement to the ATST D&D program of \$1.3M in FY 2008 above the planned \$3M, would allow NSO to continue all major aspects of the design effort, including retention of the full engineering staff and implementing final design efforts at vendors for major subsystems of the ATST.

**Table V-10. ATST Request for Additional Funds**

*(Dollars in Thousands)*

Foundation Design	300
Site A&E	200
Deformable Mirror Prototype	200
Wavefront Sensor Camera Development	200
Complete Instrument Designs at US Partner Institutions	200
Contracted Design Feasibility and Cost Analysis Studies	100
Project Management Control System Development for Baseline Review	100
<b>Total Request</b>	<b>\$1,300</b>

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 complete some of the tasks in Table V-10. These would be carefully chosen during system level reviews to maximize impact on both shortening of the schedule and overall cost.

### 3.3.2 NSO Operations and User Support

An enhancement of \$584K, or any fraction thereof, is requested for NSO operations. The maintenance items and additional facility funding requested below have been developed in light of the Senior Review and the planned ramp down and divestiture of these facilities when ATST enters the commissioning phase. The listed items are those we feel are required to maintain a safe and efficient operation over the next several years and that will provide the solar community with the support required to make a successful transition to the ATST Era.

Table V-11 places these critical items in order of priority. All of the items labeled “upgrade” will be executed in a manner that develops expertise and experience for planned ATST operations.

**Table V-11. Summary of Funding Enhancement Request**

*(Dollars in Thousands)*

<i>Priority</i>	<i>Project</i>	<i>Est. Cost</i>	<i>Project Type</i>
1	Deformable Mirror Replacement	100	Replacement
2	Deformable Mirror Electronics	100	Replacement
3	McMP Guider for the NAC	75	Upgrade
4	DST Storage Area Network	50	Upgrade
5	Road Replacement	150	Safety
6	Front-end Loader	75	Replacement
7	Staff Vehicle	25	Maintenance /Safety
8	Wireless Network	8.7	Upgrade
9	DST Weather Station	2	Replacement
<b>Total Request</b>		<b>\$583.7</b>	

Appendix E describes each of the above items in detail.

## APPENDIX A: MILESTONES FY 2008

This section describes the major project milestones for 2008.

### A1. Advanced Technology Solar Telescope

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

- ◆ Continue to develop funding partnerships for the construction phase.
- ◆ Establish vendor design completion contracts as funds become available.
- ◆ Hold final Systems Design reviews and Contract Package Reviews in advance of construction.

### A2. Solar Adaptive Optics

- ◆ Resume MCAO development at the DST
- ◆ Develop and implement stable and efficient MCAO control algorithms.
- ◆ Find optimum positions for the MCAO deformable mirrors.

### A3. Diffraction-Limited Spectro-Polarimeter On-Line Data Reduction

While still a significant effort, the scope of this development was recently limited to applying on-the-fly calibrations to DLSP data and making this calibrated data available to users via the VSO. The full inversion code is currently unavailable. Presuming labor resources are available, the milestones for FY08 include:

- ◆ Define requirements and processes.
- ◆ Develop processes.
- ◆ Implement processes.
- ◆ Conduct system testing and evaluation.
- ◆ Release system to users.

### A4. SOLIS

- ◆ Prepare a plan to handle polarization modulator degradation. This may involve a change in optical design to switch to rotating waveplates or include a detailed description of how to handle the current rate of degradation which demands a re-annealing of the modulators approximately every 2.5 years with associated significant downtime.
- ◆ Install new cameras.
- ◆ Upgrade machines to Centos, Java upgrade and CORBA upgrade.
- ◆ Assemble, test and install an extinction monitor to provide atmospheric line-of-sight conditions for the ISS instrument.
- ◆ Complete alignment of FDP instrument, making it ready for integration to mount on the SOLIS tower.
- ◆ Complete development of guider for VSM and FDP instruments.

#### A4. SOLIS (cont.)

- ◆ Continue to improve raw data reduction and calibration methods for the VSM. This includes fringe removal efforts due to polarization modulation variability during successive scan lines and the flat-field observation, as well as minor physical shifts between cameras.
- ◆ Initiate SOLIS fast-scan observations of regions likely to flare.
- ◆ Calibrate and archive new polarimetric data products from fast-scans. Isolate changes in the vector photospheric field parameters before and after flare events as observed in the fast-scan observations.
- ◆ Identify magnetic footpoints associated with polar plumes.
- ◆ Integrate VSM vector photospheric and STEREO data to calculate and compare energy budgets for coronal fields and CME's.
- ◆ Draft a plan for building a SOLIS network through partnerships.

#### A5. GONG

- ◆ Continue to develop local helioseismology methods, implement routine data production, and add new products to the archive.
- ◆ Continue to develop magnetic field products as requested by the solar physics and space weather communities.
- ◆ Develop space weather predictive tools using ring diagrams, the far-side signal, and the high-cadence magnetograms.
- ◆ Continue porting GONG's production software to Linux.
- ◆ Secure increased bandwidth from the sites sufficient to transfer full-resolution images to Tucson in near-real-time and complete the data handling system design.

#### A6. Virtual Solar Observatory

- ◆ Provide spatial search capability.
- ◆ Develop graphical user interface (GUI).
- ◆ Add more archives.
- ◆ Add additional catalogs.

#### A7. NSO Array Camera (NAC)

- ◆ Streamline NAC 1000–2200 nm polarimeter control.
- ◆ Develop looping capability in the NAC script language.
- ◆ Develop real-time flat and dark correction for the NAC.
- ◆ Purchase 50 × 50 mm square 4666 nm filter for CO lines.

#### A8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

NSO has made significant progress on SPINOR development in FY07. Unfortunately, HAO was preoccupied with higher priority projects and unable to contribute as expected. HAO recently reaffirmed their commitment to this joint project and is expected to contribute in a substantial way to deliver this project to users in FY08. The milestones for FY08 include:

- ◆ Complete SPINOR experiment control (SEC).

**A8. SPINOR (cont.)**

- ◆ Complete mechanism controls.
- ◆ Complete virtual camera and camera control computer development.
- ◆ Conduct engineering run to connect SPINOR control software to all DST facilities.
- ◆ Conduct engineering run to workout details of SPINOR operation.
- ◆ Complete data processing package.
- ◆ Conduct science run with staff scientist
- ◆ Release instrument to user community.

**A9. Facility IR Spectropolarimeter (FIRS)**

This joint effort with University of Hawaii is currently in the implementation phase at the DST. The milestones for FY08 include:

- ◆ Finalize the optical bench layout for 0.632 and 1.56 microns.
- ◆ Complete the mechanical work.
- ◆ Implement storage area network (SAN) access and integrate FIRS into DST mechanisms via the common services server.
- ◆ Conduct science runs.
- ◆ Release the instrument to the user community

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

The scope of this effort was limited to replacing the cantankerous CAMAC system. Good progress on this effort was made in FY07 and the primary milestones for FY08 include:

- ◆ Implement new A2D/D2A.
- ◆ Implement new motion control of instrument computer control (ICC) and specific port-4 mechanisms.

**A11. Rapid Oscillations in the Solar Atmosphere (ROSA) Imaging System**

The Queen's University Belfast group is planning to bring this instrument for integration into the DST in the summer of 2008.

**A12. DST Data Storage Upgrade**

This project focuses on replacing the current DLT media storage with portable SATA hard drives, upgrading the capacity of the SAN, and increasing capacity for a temporary archive. The milestones for FY08 include:

- ◆ Develop project requirements and scope.
- ◆ Identify processes to be developed.
- ◆ Develop and implement processes.
- ◆ Test and release.

**A13. McMath-Pierce Telescope Control System (TCS) Upgrade**

- ◆ Replace existing Dec PDP-11.73 telescope control computer with a modern PC running a PDP emulator.

- Acquire emulator and associated I/O hardware.
- Configure system to emulate existing components (I/O, tape drive, etc.).
- Load and configure the operating system, Kitt Peak Multitasking Forth, onto the emulator system.
- ♦ Implement a 2D translating limb-guider system.
  - Specify and design.
  - Reconfigure and mount the Infrared Adaptive Optics (IRAO) bench below the spectrograph rotating table to accommodate the limb-guider platform.
  - Acquire the limb sensors, manufacture the required hardware and assemble.
  - Interface to the spectrograph rotation encoder, NAC and IRAO fast tip-tilt mirror.
  - Develop the control and interface software.
  - Test and refine the precision pointing algorithms and ephemeris.

#### **A14. Planetary Adaptive Optics System for the McMath-Pierce Telescope**

- ♦ Finalize the wavefront sensor optical design.
- ♦ Conduct initial testing.
- ♦ Mount the system on the McMP stellar spectrograph.
- ♦ Conduct final testing and first science observations.

#### **A15. Integrated Field Unit (IFU) for the McMath-Pierce**

- ♦ Mount IFU on the spectrograph ahead of the input slit.
- ♦ Develop alignment procedure.
- ♦ Test and characterize performance/
- ♦ Release instrument to users.

#### **A16. Establish NSO Headquarters**

- ♦ Develop a draft of plans.
- ♦ Establish guidelines in coordination with AURA and NSF.

## APPENDIX B: STATUS OF FY 2007 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2007 Program Plan. (FY 2007 milestones appear in italics below.)

### B1. ATST

- ◆ *Present the project to the National Science Board for inclusion in the MREFC funding line.*

The NSB considered the ATST project at their August 2007 meeting and announced the following: "RESOLVED, that the National Science Board authorizes the Director at his discretion to include the construction of the Advanced Technology Solar Telescope in a future budget." The project continues to work with the funding agency to establish baseline funding profiles and schedules.

- ◆ *Continue to develop funding partnerships for the construction phase.*

Discussions were held with potential partners, which included Japan, Italy, United Kingdom, Ireland, Germany, and Canada.

- ◆ *Establish vendor design completion contracts as funds become available.*

Preparations of request for proposal (RFP) packages for industry construction contracts are well underway for the major sub-assemblies. Contract package reviews are scheduled for the summer of 2008.

### B2. Solar Adaptive Optics

- ◆ *Develop and implement stable and efficient MCAO control algorithms.*

In progress.

- ◆ *Find optimum positions for the MCAO deformable mirrors.*

In progress.

- ◆ *Continue MCAO observations.*

MCAO development was put on hold as efforts from the AO group were focused on ATST design and performance contracts and preparations for two major design reviews.

- ◆ *Off-load AO signals to the DST guider system.*

The off-load was successfully completed.

### B3. Diffraction-Limited Spectro-Polarimeter (DLSP)

- ◆ *Define and develop baseline project plan for the online data reduction effort.*

- ◆ *Develop reduction applications.*

- ◆ *Install new hardware.*

- ◆ *Conduct engineering observations at the DST.*

This project was put on hold due to limited labor resources and lack of project definition. However, project planning has recently resumed.



## B4. SOLIS

- ◆ *Develop an upgrade path for the VSM cameras.*

Three cameras (one spare) have been purchased and delivered from Sarnoff with modifications to better meet the VSM scientific requirements. Modifications included better synchronization, operation at 300 Hz frame rate, and increased linear full-well capacity. Data output of the new cameras was incompatible with the existing Data Acquisition System (DAS) and therefore required engineering changes. Work on the new DAS to replace the current, non-supportable SOLIS digital signal processing (DSP)-based system, has progressed well. The new DAS hardware configuration supports the Sarnoff camera link format and eliminates the current 8 MB/s VxWorks PMC VI fiber bottleneck when sending data to the storage area network (SAN). The new DAS software has been written and tested, using camera simulators, which allow one to match the Sarnoff 300 Hz frame rate and array size of  $1024 \times 256$ . Qualification tests and finalization of the complete DAS and camera system is expected within the first quarter of FY08.

- ◆ *Assemble, test, and install an extinction monitor to provide atmospheric line-of-sight conditions for the ISS.*

Calibration of the Integrated Sunlight Spectrometer requires an extinction monitor to account for sky transmission, and an iodine cell for absolute spectral-line shift. The filters within the extinction monitor are currently being adjusted to accommodate the spectral sensitivity characteristics of the new Sony “FLEA” camera. The wide range of intensities and limited space for trim filters has been problematic. An iodine cell was fabricated in-house but did not meet the strict requirement regarding fringes. A commercial company was then contracted and built an iodine cell with orthogonally mounted wedged windows that should meet the requirement of no fringing. Qualification testing of both the iodine cell and extinction monitor is expected to begin in the first quarter of FY08, with full implementation of a calibration routine to follow later in the year.

- ◆ *Complete alignment of FDP instrument, making it ready for integration to mount on the Kitt Peak SOLIS tower.*

The Full-Disk Patrol will record full-disk intensity images of the Sun using filtered portions of spectrum lines regarded as important to the study of solar activity. Similar observations are available from other sources; therefore, completion of this final instrument for the SOLIS three-instrument suite was the last to be scheduled. Currently, all major hardware has been purchased and 80% of the operating software has been developed. Hardware tasks include changing the SMD camera data acquisition system to the SOLIS standard, assembling one Lyot tunable filter, installation of the guider, mounting and aligning beam splitters, and overall optical alignment. Remaining software tasks include debugging current software for mechanism control, creating code to tune the Lyot filters, and developing routines to reliably operate the instrument in a synoptic manner. In addition, calibration and data processing algorithms are required for FDP observations before the instrument is put on line. Once the instrument has passed qualification testing in the lab, it will be moved to Kitt Peak and installed beside the VSM on an independent declination mount. Currently, the instrument is expected to be fully assembled by the end of FY08, with lab qualification tests to take place in the first quarter of FY09.

- ◆ *Complete development of guider for VSM and FDP instruments.*

The original SOLIS guider was redesigned in order to reduce noise and meet scientific requirements. Testing of the new circuit, in quad-cell mode, has demonstrated that the design functions well when using one of four linear arrays. However, lack of sufficient memory in the current data processing board would not allow signal processing of two arrays at the required rate. An upgraded version of the signal processing board was obtained from the original board manufacturer at no cost for testing purposes. The improved

board version is expected to deliver the desired performance, has the same physical footprint as the original board, and is compatible with all operational software written to date. The design, spare boards, and components have been offered at no cost if the system meets our requirements. After installing the new guider design, operating in quad-cell mode, into the Full-Disk Patrol (FDP), additional boards will be assembled, software changed for limb scanning, and the slit hardware modified for embedding the guider into the SOLIS VSM. The four linear arrays are parallel to the entrance slit and provide an accurate guiding signal to the secondary mirror tip/tilt system and the mount. Regular operation of the VSM guider system is expected by the third quarter of FY08.

◆ *Provide a larger complement of observing programs and data products.*

The ISS is taking daily observations (weather permitting) with the following wavelengths 388.4 nm, 396.8 nm, 538.0 nm, 539.4 nm, 656.3 nm (H-alpha), 854.2 nm, and 1083.0 nm; although only the Ca II K, Ca II K H, and 1083.0 nm are currently available on the Web. These lines correspond to the wavelengths Bill has been observing with the McMath-Pierce spectrometer. Daily Ca II K data (393.4 nm) started on 20061202, Ca II H (396.8 nm) and 1083.0 nm began on 20070427. Daily observations for the remaining lines began on 31 August 2007 after corrections were made to the grating position algorithm.

Quick-look vector magnetic FITS-formatted data and JPEG image files are now available for recent observations with the VSM. The quick-look vector data is also available in x3d format such that the data can be explored as a 3D model.

◆ *Prepare initial science papers.*

The following represent the publications published and submitted during FY07. Not included are oral and poster presentations at meetings that did not result in a paper in print.

1. Raouafi, N.-E., Harvey, J. W., and Solanki, S. K. "Properties of Solar Polar Coronal Plumes Constrained by Ultraviolet Coronagraph Spectrometer Data," *ApJ*, 658, 643-656.
2. Harvey, J. W., Branston, D., Henney, C. J., and Keller, C. U. "Seething Horizontal Magnetic Fields in the Quiet Solar Photosphere," *ApJ*, 659, L177-L180.
3. Raouafi, N.-E., Harvey, J. W. and Henney, C. J. "Latitude Distribution of Polar Magnetic Flux in the Chromosphere Near Solar Minimum," *ApJ*, in press.
4. Komm, R., Howe, R., Hill, F., Miesch, M., Haber, D., and Hindman, B. "Divergence and Vorticity of Solar Subsurface Flows Derived from Ring-Diagram Analysis of MDI and GONG Data," *ApJ*, 667, 571-584.
5. Marcon, R., Kaufmann, P., Melo, A. M., Kudaka, A. S., and Tandberg-Hanssen, E. "Association of mid-infrared solar plagues with Calcium K line emissions and magnetic structure," *PASP*, in press.
6. Georgoulis, M. K., Raouafi, N.-E., and Henney, C. J. "Automatic Active-Region Identification and Azimuth 6. Disambiguation of the SOLIS/VSM Full-Disk Vector Magnetograms," *Proceedings of the NSO Workshop 24, ASP Conf. Series*, in press.
7. Svalgaard, L. and Cliver, E. W., "A Floor in the Solar Wind Magnetic Field," *ApJ*, 661, pp. L203-L206.

◆ *Draft a plan for building a SOLIS network through partnerships.*

The current cost estimate to replicate the VSM is approximately \$5.5M (full-cost accounting with an estimated 20% error) in FY 2007 dollars. The VSM currently in operation on Kitt Peak will require some redesign in order to (i) update various electronic components; and (ii) increase the ease of maintenance. In the past year, presentations were given to potential partners in Algeria and Germany. The Germans expressed a strong interest in utilizing SOLIS data as the observational basis for the development of models

of magnetic flux evolution. However, they also noted that their national funding for initiatives in solar physics currently is dedicated to completing the Gregor telescope. The Algerians approached the NSO with a commitment of \$2.5M for the development of their national program in solar physics and identified the SOLIS VSM as a cornerstone instrument for their participation in the forefront of observational solar physics. However, the cost estimate of \$5.5M for the replication of the VSM has led the Algerians to resume further internal discussions of their priorities.

In January 2008, NSO will submit a pre-proposal to the NSF/Atmospheric Sciences Division Mid-Size Infrastructure (ATM/MSI) Opportunity program to build two near-duplicates of the VSM in the Canaries (Spain) and Western Australia (Learmonth). Oskar von der Lühe and Pere Pallé (KIS, Germany and IAC, Spain) and Phil Wilkinson (Director, Ionospheric Prediction, Radio and Space Services, Australia) have indicated their strong interest in participating in the network. NSO will rely on these partners to support the operation of the VSMs at their respective sites, which are also GONG sites. Should NSO be invited to submit a full proposal following peer review of the pre-proposal, letters of commitment with details of the support provided by the international partners will be negotiated and included in the full proposal, which is due 02 June 2008.

The NSO will continue to refine the current cost estimates and seek partners for a SOLIS VSM global network.

## B5. GONG

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

A database of emerging active regions has been prepared, and will be used as input for a “custom patch” interface that will provide improved local helioseismic sampling of active regions and other solar features. The time-distance pipeline is still on hold, pending further refinements to the magnetogram processing pipeline.

- ◆ *Calibrate the farside signal.*

An initial calibration has been developed. An improved calibration is underway, based on a new method that can project the far-side signal onto the near side, thereby removing the unwarranted assumption that the magnetic field does not change as it transits the far side.

- ◆ *Continue porting GONG's production software to Linux.*

In general, progress has been slowed due to data precision issues and the need to share resources to develop and implement the magnetogram pipeline, which was a higher priority in 2007.

- ◆ *Implement the magnetogram production pipeline and archive data products.*

Substantial progress has been made, particularly in the implementation of a near-real-time capability that now produces continual ten-minute average full-disk magnetograms, hourly synoptic maps, and eight different projections of the extrapolated magnetic field in the corona.

- ◆ *Complete the fabrication of mechanical parts and production of custom electronics for the Hot Spare.*

This has been completed. However, integration of the hot spare instrument is on indefinite hold in light of the Senior Review recommendations.

- ◆ *Secure increased bandwidth from the sites sufficient to transfer full-resolution images to Tucson in near-real-time and complete the data handling system design.*

Substantial progress has been made with the implementation of the near-real-time magnetogram production pipeline and the far-side pipeline. The project to transfer near-real-time full-resolution data from the remote network sites is still in progress.

## B6. Virtual Solar Observatory

- ◆ *Provide spatial search capability.*  
Not yet done
- ◆ *Develop graphical user interface (GUI).*  
Improvements have been made to the design of the search results pages
- ◆ *Add more archives.*  
Added STEREO, and Hinode data sets.
- ◆ *Add additional catalogs.*  
None added this year.
- ◆ *Add spectral portal if University of Washington proposal is successful.*  
Proposal not submitted, capability is deferred.

## B7. NSO Array Camera (NAC)

- ◆ *Conduct tests of mid-IR polarimeter components.*  
Quotes from two vendors were requested, but neither currently fabricates the retarding optics for the 3000-5000 nm range. Discussions with NASA instrument developers were made, and it was determined that they would help in the search for a vendor who could provide the optics needed for building a NAC mid-IR polarimeter. The project remains on hold until a vendor is identified.

## B8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- ◆ *Complete project design documentation.*  
The majority of the design documentation was completed by the NSO project lead engineer (Chris Berst). Craig Gullixson also played a major in developing the Common Services Server documentation.
- ◆ *Develop SPINOR experiment control.*  
This major section of SPINOR development belongs to the High Altitude Observatory (HAO). Due to higher priorities and lack of labor resources at HAO, this activity has fallen behind.
- ◆ *Develop Port 4 mechanism control.*  
Excellent progress has been made by the NSO group. The NSO effort on this task is mostly completed.
- ◆ *Develop virtual cameras and camera control computers.*  
Excellent progress by the NSO group in this area as well. These tasks are scheduled for completion by 2008.
- ◆ *Complete associated hardware development.*  
80% completed by NSO.

## B9. IR Polarimeter

- ◆ *Conduct engineering runs at the DST.*

Two engineering runs were completed and they continue into FY08.

- ◆ *Finalize polarimeter optical design.*

Good progress has been made. However, due continuing changes to the optical requirements, the milestone is not complete.

- ◆ *Develop optical/mechanical feed from the DST AO.*

Completed.

- ◆ *Install optical bench.*

Completed.

- ◆ *Complete mechanical fabrication.*

Most of the mechanical fabrication was completed. The last major mechanical task will not be completed until the optical design has is frozen.

- ◆ *Integrate DST Common Services Server protocol.*

Not started due to higher priorities.

- ◆ *Conduct shared risk observations.*

Not started as the project remains in the engineering phase

## B10. Dunn Solar Telescope Critical Hardware (System Upgrade)

- ◆ *Complete the requirements document for the critical hardware replacement.*

Completed.

- ◆ *Replace Computer Automated Measurement And Control (CAMAC) system.*

Very good progress has been made by Kit Richards. Many of the major telescope functions are now under the new VME control. The two major tasks remaining include the A2D/D2A and motion control replacements. This effort is scheduled to conclude by the summer of 2008.

- ◆ *Replace amplifiers.*

Not started.

- ◆ *Replace NATEL.*

Not started.

- ◆ *Develop new hand-box.*

Completed. The existing hand box was modified to work with the new control system.

## B11. Rapid Oscillations in the Solar Atmosphere (ROSA) Imaging System

- ◆ *Provide Queen's University Belfast with technical design support as needed.*

Completed.

**B12. DST Data Storage Upgrade**

- ◆ *Define requirements.*  
Completed.
- ◆ *Develop use cases.*  
Completed.
- ◆ *Develop upgrade plan.*  
75% completed.
- ◆ *Develop software and hardware as required.*  
50% completed.
- ◆ *System testing and evaluation.*  
50% completed.

**B13. McMath-Pierce Telescope Control System (TCS) Upgrade**

- ◆ *Release RFQ to control system vendors.*
- ◆ *Refine scope and requirements as needed in negotiation with vendors.*
- ◆ *Secure contract with vendor.*

A detailed technical request for quote (RFQ) was written and distributed to vendors for bids in 2007. Unfortunately, the quotes received for the project were significantly above what had been budgeted, resulting in the need for a new approach. Lower cost options are being investigated. See Section 2.2.2. (page 15).

## APPENDIX C: NSO FY 2008 BUDGET & STAFFING SUMMARY

### NSO FY 2008 Budget Summary

(Dollars in Thousands)

<i>Expenses</i>	Director's Office	Sunspot	Tucson	GONG	ATST	SOLIS	Total Budget
Director's Office	259				110		369
Scientific Staff		384	450	875	310	155	2,175
Scientific Support/Computing		294	210	699			1,203
Instrument Development/Maintenance		685	221	274	340		1,520
Telescope Operations		219	224	640		540	1,623
Facilities		619					619
Administrative Support		266		182			448
Educational & Public Outreach	111	152	59				321
NOAO Business Support	17	147	343	245	118		869
ATST					2,943		2,943
AURA Management Fee	272				57		329
<b>Program Total</b>	<b>658</b>	<b>2,766</b>	<b>1,508</b>	<b>2,916</b>	<b>3,878</b>	<b>695</b>	<b>12,421</b>
<i>Revenues</i>							
Programmed Indirects/Carry Over	(25)	(59)	(91)	(105)			(281)
Housing Revenue		(104)					(104)
Meal Revenue		(17)					(17)
NSF REU/RET Funding		(60)	(59)				(119)
AF Support		(400)					(400)
ATST Fellowship Support					(150)		(150)
Visitor Center Revenue		(50)					(50)
<b>NSF/AST Funds</b>	<b>633</b>	<b>2,076</b>	<b>1,358</b>	<b>2,811</b>	<b>3,728</b>	<b>695</b>	<b>11,300</b>

### FY 2008 Staffing Schedule

(In Full-Time Equivalents)

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

## APPENDIX D: SCIENTIFIC STAFF RESEARCH AND SERVICE

### Olga Burtseva, Research Associate

#### Areas of Interest

Local Helioseismology, Time-Distance Analysis

#### Recent Research Results

O. Burtseva studied the influence of the active region that emerged on the solar surface in October 2003 on travel-time measurements. Travel time maps of acoustic waves with two different phase speeds computed and the spatial distribution of the travel times investigated as changes in the spatial power spectrum of the travel times may be useful for detecting an emerging active region. The results of this pilot study suggest that only very subtle changes in the travel-time spatial power spectrum might be caused by active region emergence. However, other choices of phase-speed filter parameters may produce different results. A statistical study is therefore necessary. The results of this work were discussed at the NSO Workshop #24 on "Subsurface and Atmospheric Influences on Solar Activity in April 2007.

Influence of surface activity on the latitudinal distribution of travel times of acoustic waves in the upper solar convection zone was studied. The mean travel times for two wave packets propagating down to 12.1 and 14.5 Mm were computed up to 45 degrees in latitude and compared at solar minimum and maximum. The results show that latitudinal variations of the mean travel time are mostly caused by the presence of active regions.

Excluding active regions from the cross-correlation analysis with a masking method reduces the travel-time difference between solar maximum and minimum only in active latitudes but doesn't eliminate the latitudinal dependence of the travel times completely. At non-active latitudes, the travel times are about 0.5 seconds shorter at solar maximum in comparison with those at solar minimum. This might be evidence of global changes in latitudinal distribution of sound speed over the solar cycle. These results were presented at the HELAS II Conference in Germany in August 2007.

A time-distance technique was applied to analyze a set of artificial data computed by S. Hanasoge (HEPL, Stanford) using 3D Euler equation solvers in spherical geometry. The results of the test comparison of the simulated data with GONG data are consistent in general. Artificial data will be necessary to test and calibrate the time-distance measurements.

At present, Burtseva is working on comparison of lifetimes of high- $\ell$  solar  $p$ -modes at solar minimum and maximum. The results show that solar maximum lifetimes are systematically shorter in comparison with those at solar minimum. This may be related to the known fact that magnetic regions absorb the  $p$ -mode waves. A method of active-region masking was applied in an attempt to determine whether the shift is a result of the effect of active regions, or the result of global changes of the solar plasma properties with the solar cycle. In the quiet region of the solar disk, lifetimes are still systematically shorter at solar maximum but less in quantity. An attempt to compute lifetimes in a sunspot are currently being performed.

#### Future Research Plans

Burtseva plans to continue investigating pre-emergent active regions with time-distance analysis.



## **Mark S. Giampapa, Astronomer**

### **Areas of Interest**

Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

### **Recent Research Results**

Giampapa and his collaborators published a paper in *The Astrophysical Journal* on the results of their long-term 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. One surprising result of this work was the discovery of solar-type stars that are noticeably more active than the Sun as seen at solar maximum. This may indicate that the potential excursion in the solar cycle is greater than seen so far in contemporary measurements or that these particular M67 stars are rotating more rapidly, which would be unusual for a cluster of this age.

### **Future Research Plans**

Giampapa and his collaborators intend to follow-up the M67 study with an observational program that will focus on other activity diagnostics and projected rotation measures. Time has been allocated on the ESO VLT with collaborator Ansgar Reiners (University of Göttingen). Giampapa will continue his participation in the joint University of Arizona/NOAO NASA Astrobiology program. Giampapa is a Co-Investigator in this program where his efforts focus on delineating the nature and evolution of the variable activity of solar-type stars that may be the hosts of extrasolar planetary systems. Specifically, Giampapa and his collaborators, including NASA-funded postdoc William Sherry, will examine the joint variation of irradiance and chromospheric (magnetic) activity in Sun-like stars in clusters ranging in age from ~100 Myr (e.g., the Pleiades) to solar age (e.g., M67 and possibly older clusters) in order to characterize the ambient radiative and deduced particle environments within which the evolution of planetary atmospheres occurs. In addition, a spectroscopic investigation of the chromospheric activity in Ca II H and K in the Pleiades and the intermediate-age cluster NGC 752 will be pursued in collaboration with S. Baliunas (SAO) using the MMT Hectochelle.

### **Service**

M. Giampapa is the deputy director for the National Solar Observatory. In this role, Giampapa assists the NSO director in the development of program plans and budgets, including budgetary decisions and their implementation, and the preparation of Observatory reports and responses to NSF and AURA oversight committee requests. Giampapa currently serves as chair of the NSO Scientific Personnel Committee, which advises the director on personnel actions involving the scientific staff, including hiring and promotion. He also carries out supervisory responsibilities for the NSO Tucson/Kitt Peak program. In this role, he has overview responsibilities for the scientific and instrument development activities at NSO/Kitt Peak, including the SOLIS project, and the conduct and support for observing programs at the NSO McMath-Pierce Solar Telescope Facility on Kitt Peak. Giampapa is the PI for SOLIS as well as the instrument scientist for the SOLIS Integrated Sunlight Spectrometer (ISS); chair of the Kitt Peak Telescope Allocation Committee (TAC); chairman of the Tucson site Project Review Committee (PRC) and serves as a member of the full NSO PRC; and, program scientist for the McMath-Pierce nighttime program. Giampapa represents the NSO on the NOAO Management Committee. He also serves as an editorial board member for *New Astronomy Reviews*. Like other NSO scientific staff members, Giampapa participates in educational outreach activities, including K-12, undergraduate, graduate, and general public educational programs and activities. Giampapa is an adjunct astronomer at the University of Arizona.

**Irene González Hernández, Assistant Scientist****Areas of Interest**

Local Helioseismology (Seismic Imaging and Ring-Diagram Analysis)

**Recent Research Results**

González Hernández works on the GONG far-side project, aimed at calculating daily far-side maps of the Sun's magnetic activity. Daily maps are shown on the GONG Web site (<http://gong.nso.edu/data/farside/>). González Hernández and collaborators have recently published the first calibration of the far-side seismic signal by analyzing maps calculated using more than four years of GONG continuous data. Relationships between the calculated phase-shift and certain characteristics of the active regions such as size and magnetic field strength were found and will be used in the near future to improve the far-side monitor. González Hernández is also involved in the GONG Ring Diagrams pipeline and has been researching the meridional flow temporal variation from standard ring analysis of five years of data, in particular, the effect of magnetic activity in such measurements.

**Future Research Plans**

González Hernández is currently working on far-side images that extend all the way to the front side in order to enhance the magnetic calibration and help to understand other solar features in the maps. She is also working on automating the monitor to predict the appearance of large active regions on the frontside. González Hernández plans to compare meridional flows for high and low magnetic activity periods to try to understand the influence of magnetic features on the measured flows from ring analysis. She has recently started to collaborate on a project to characterize the dynamics in the photosphere below emerging active region.

**Service**

González Hernández participated in the NSO 2007 Research Experiences for Teachers (RET) summer program as mentor to middle-school teacher Helena Freedlund. She advised Freedlund on a project involving the development of a catalogue of emerging active regions that can be accessed at <http://gong.nso.edu/emerging/>.

**John W. Harvey, Astronomer****Areas of Interest**

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

**Recent Research Results**

During FY 2007, J. Harvey worked on SOLIS and GONG instrument development and maintenance, on a NASA-funded effort to correct errors in and modernize the archive of Kitt Peak Vacuum Telescope data (KPVT), and started to do some research using GONG and SOLIS data. Harvey presented an invited review paper "Chromospheric Magnetic Fields" at an international meeting. Work continued with J. Sudol (Gettysburg College) on a systematic study of magnetic field changes associated with flares observed with GONG. With N.-E. Raouafi and C. J. Henney, a study of the latitude distribution of polar magnetic flux was completed and published. An investigation of transient features visible in Hinode XRT images with respect to the structure and dynamics of the underlying magnetic field was started. The new availability of high-cadence x-ray and magnetic images from GONG makes this study very timely. Harvey's most unexpected discovery was finding a ubiquitous, seething, horizontal magnetic field in the quiet photosphere. This new component of the solar magnetic field went unnoticed for decades and was confirmed by Hinode observations. The work was published early in 2007.

### Future Research Plans

During FY 2008, J. Harvey will continue to concentrate on development of SOLIS and GONG. In particular, new cameras and a more robust modulator for the SOLIS/VSM, completion of the SOLIS/FDP and characterization of a new camera for GONG. He intends to revive code to produce synchronic synoptic maps for use with KPVT, SOLIS and GONG data. With C. J. Henney, a paper on the chromospheric magnetic field as observed with SOLIS is in preparation. A study of inner network magnetic field variations since 1975 will be continued.

### Service

J. Harvey continues as Project Scientist for SOLIS, and Instrument Scientist for GONG. Harvey will chair a committee to review the Solar and Plasma Astrophysics Division of the National Astronomical Observatory of Japan (NAOJ) and will be a member of a committee to review the entire NAOJ.

## **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, in collaboration with J. Harvey, analyzed high-cadence photospheric and chromospheric longitudinal magnetogram time-series data observed by the SOLIS vector spectromagnetograph. This work found a new "seething" ubiquitous horizontal magnetic field component in the photosphere, and is published in *ApJ Letters*. Henney also collaborated with N.-E. Raouafi and J. Harvey, on a study of the latitudinal distribution of flux using VSM chromospheric longitudinal magnetograms. This work found a strong latitudinal dependence for the distribution of magnetic flux in the polar regions, and is published in *ApJ*. Henney, in collaboration with M. Georgoulis and N.-E. Raouafi, also worked on the incorporation and testing of code to automatically select active regions and disambiguate VSM quick-look vector magnetic products. He also continued cross-calibration analysis of SOLIS VSM and KPVT photospheric magnetograms. Preliminary results show that the VSM 630.25 nm magnetograms are more sensitive to both quiet Sun weak field and sunspot strong field regions.

### Future Research Plans

The primary research tasks for Henney, in the near-term, include calibration of the old and new SOLIS VSM cameras. Once the instrumental polarization signals have been minimized for the VSM Stokes profile spectra, Henney's research activities will follow two key paths defined by spatial scale, that is, active region and global scales. The VSM vector data will be employed to give the magnetic field context for SOLIS FDP observations of sunspots, filaments, flares and coronal mass ejections. Besides magnetic field inversions of active region data for better parameterization of pre- and post- flare and coronal mass ejection events, the global magnetic field configuration is of great interest. The global field analysis will include the comparison of active region helicity between the hemispheres and during the solar cycle with the planned creation of magnetic helicity synoptic maps.

In addition, Henney's research plans include the study of the dependence of weak solar magnetic field emergence on latitude and the solar activity cycle. This research will include daily high cadence photospheric (at one-minute cadence) and chromospheric (at a cadence of one and five minutes) area-scans (for durations of approximately one hour) at the equator, mid-latitudes, and polar regions to study the cycle variation of bipole flux emergence rates, size scales and strengths. These high cadence area-scans will also be utilized to further the understanding of the "seething" horizontal magnetic field and the magnetic power spectrum evolution of umbral and penumbral regions.

Henney's continuing research will include improving the solar wind forecasting based on coronal hole estimation synoptic maps derived from VSM He I 1083 nm data. In addition, continuing joint observations and comparison with the SOLIS ISS and the McMath/Pierce observation by Bill Livingston and those of the Sacramento Peak Evans Facility instrument will be active areas of study. After completing the cross-calibration of the VSM and KPVT full-disk mean longitudinal magnetic field data sets, a follow-up study of the phase coherence of magnetic activity between solar cycles is of considerable interest. This phase coherence analysis is also planned to be applied to the SOLIS ISS Ca II H and K parameters to study the global solar atmospheric response to solar magnetic fields and the solar cycle.

#### Service

As interim Program Scientist for the SOLIS project, Henney oversaw the daily operations of the SOLIS VSM. Henney also served as the interim Program Manager for the SOLIS project for the first half 2007. As Data 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. In this role, he continued to develop and maintain the data reduction procedures for the production of SOLIS-VSM 630 and 854 nm longitudinal data products. The processing, in addition to the temporary storage and archiving, of the raw VSM spectral data was managed by Henney. He also worked on the development and implementation of the algorithms to apply longitudinal magnetic bias correction, along with geometric corrections to the VSM data products. Henney also continued to maintain and modify the synoptic data pipeline, previously designed for KPVT data, to produce VSM synoptic products as part of the SOLIS DHS. In addition, he developed and maintained the SOLIS Web pages for public access to VSM data products, which include daily magnetograms and synoptic maps. Henney also oversaw the weekly VSM Vector Working Group (VSWG) meetings. Additionally, Henney continued collaboration with F. Hill and H. Jones in the development and management of the "Researching Active Solar Longitudes" (RASL) educational research project, in addition to new educational activities, part of the "Data and Activities for Solar Learning" (DASL) project.

### **Frank Hill, Senior Scientist**

#### Areas of Interest

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

#### Recent Research Results

Hill continues to perform research in helioseismology. Recent work with S. Tripathy, K. Jain, and J. Leibacher has focused on measuring variations in the oscillation frequencies on nine-day time scales. This work has shown that the sensitivity of the frequency shifts on the activity changes throughout the solar cycle. This suggests that there are two components to the shift—one arising from the weak background fields, and another caused by the evolution of active regions.

Working with Shukur Kholikov, Hill has been investigating the use of the autocorrelation function of low-degree  $p$ -mode time series to measure the time it takes for a  $p$  mode to travel completely through the Sun. This method provides measurements that are a factor of 50 more precise than using the power spectrum, and has revealed for the first time a temporal variation correlated with the solar cycle. The method should work quite well for asteroseismology studies of stellar interiors.

#### Future Research Plans

Hill plans to probe the lower convection zone with large-aperture ring diagrams. These studies will be used to search for deep meridional flows required by current dynamo theories, as well as longitudinal structure of the tachocline, the region of the solar interior where the rotation profile changes from differential to solid-body.

In addition, Hill will begin work on a direct 3-dimensional inversion of ring diagrams to estimate the vertical and horizontal flow fields in a self-consistent way. He also hopes to extend the modeling of the effect of spectral line profile changes on helioseismic inferences to include different atmospheric heights.

#### Service

Hill is the GONG program scientist and is managing the GONG Program. He also continues as the GONG data scientist, overseeing the development of algorithms for the reduction and analysis of data for helioseismology. Hill serves as the NSO digital library scientist, placing NSO and SOLIS data on-line and accessible over the Internet. He is participating in the development of the Virtual Solar Observatory, which was released to the public in December 2004. He is also taking part in the Collaborative Sun-Earth Connection (CoSEC) project. Hill typically supervises several staff, currently seven scientists, one manager, and one programmer. He is a member of the IAU Working Group on International Data Access, and the NSO/Tucson Telescope Allocation Committee. He participates in the NOAO TLRBSE program, producing a software package to reduce and analyze McMath-Pierce NIM and NAC IR data.

### **Rachel Howe, Associate Scientist**

#### Areas of Interest

Helioseismology, the Solar Activity Cycle, Peak Fitting

#### Recent Research Results

Further work on the solar rotation, on solar-cycle changes over 11 years of medium-degree observations, and on local frequency variations from ring-diagram analysis is ongoing and in preparation. Howe is currently writing an invited review article on "Solar Interior Rotation and its Variation" for *Living Reviews on Solar Physics*. She is a co-investigator on the Helioseismic and Magnetic Imager (HMI) instrument to be launched aboard the Solar Dynamics Observatory (currently scheduled for launch in 2009) and as such attended the HMI team meeting held in Stanford, CA in February 2007.

#### Future Research Plans

Howe intends to continue working on the above areas.

#### Service

In addition to the research activities described above, Howe shares with R. Komm the (informal) responsibility for checking the results of both the GONG PEAKFIND analysis and the 'ring diagram' pipeline that is currently under development. Howe also maintains the layout for the GONG resources CD, of which many copies were distributed at the 2007 AAS/SPD meeting. She assisted with the organization of the 2007 NSO Summer Workshop, with particular responsibility for preparing the abstract booklet and editing the proceedings volume, to be published by in 2008 as ASP Conference Series Volume 383, Subsurface and Atmospheric Influences on Solar Activity.

### **Stephen L. Keil, NSO Director**

#### Areas of Interest

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

#### Recent Research Results

Keil worked with Steve Tomczyk of the High Altitude Observatory (HAO), Tom Schad, a 2006 NSO REU student from Notre Dame, and 2006 NSO RET teacher Daniel Seeley from Farmington High School in Massachusetts on the study of coronal waves. An eight-hour time sequence of Doppler velocities obtained at

a 30 second cadence in the coronal 1074.7 nm line with the HAO Coronal Multichannel Polarimeter (CoMP) mounted on NSO's Coronal One-Shot telescope were used to measure MHD and magneto-acoustic waves. They found propagating coronal waves that demonstrated Alfvénic velocities low in the corona, slowing to fast kink-mode velocities at about 1.2 solar radii. Keil also collaborated in SOHO JOP178 and is co-authoring a paper on the causes of filament eruptions and subsequent CMEs and flares.

#### 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 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. The work on coronal waves will attempt to make higher cadence observations.

#### 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 is a member of the AAS/SPD Prize Committee.

### **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. He has developed a time-distance pipeline, which provides travel-time maps of daily GONG-network data and produces reconstructed images with specified filters. At present, an IRAF-independent version of the pipeline has been implemented. The pipeline may produce Spherical Harmonic time series using daily merged velocity images.

The main focus of the pipeline is meridional flow measurements. It is well known that most variations of meridional flow are caused by the presence of active regions. Eliminating the active regions from the computation domain was investigated using GONG data on two time periods: 2001 and 2006. Preliminary results show non-significant changes in meridional flows during the solar cycle, when active regions are excluded from the analysis. All of the changes are located at active latitudes.

Time variations of meridional flow are important for understanding the solar dynamo model. Attempts to see the changes in meridional flow were unsuccessful since the projection effects on the measurements were an issue. About one year of periodicity was found in the mean travel times. The nature of this periodicity is not yet clear. The reason for this periodicity might be due to incomplete correction for the B-angle, which also varies within the one-year period. A comparison of the measurements for different B-angle time periods is necessary in order to understand B-angle dependence of the above periodicity. This work is still in progress.

Kholikov has found that an autocorrelation analysis of the low-degree time series can provide a very sensitive measurement of the large separation, the frequency difference between modes with the same degree but different radial order. This has revealed that the large separation varies with the level of solar activity, indicating that the depth of the upper reflection point of the modes depends on the activity. Use of both GONG and MDI data sets has allowed the acquisition of very precise measurements of large separation using a time-distance technique. From a time-distance approach, location of the peaks in autocorrelation functions represents an acoustic radius of the Sun. A very good

correlation of acoustic radius changes with the solar activity cycle has been obtained from both data sets. Results of this work have been submitted to *Solar Physics*.

#### Future Research Plans

Kholikov will continue to improve the time-distance pipeline and provide the scientific community with specific GONG data for local helioseismology analysis. The main focus will be time variations of meridional flow and the masking problem of active regions.

### **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 F. Hill, and R. Howe). Using these descriptors, he was able to derive, for example, the divergence and vorticity of solar sub-surface flows and study their relationship with magnetic activity, and compare the divergence-vorticity relationship with large-scale simulations (in collaboration with M. Miesch (HAO/NCAR)). Komm is also studying the daily variation of the divergence of emerging active regions (in collaboration with S. Morita (ISAS/JAXA, Japan)) in order to detect a signature of flux emergence in sub-surface dynamics. In addition, Komm has begun exploring the relationship between the daily variation of the twist of subsurface flows and the emergence and flare production of active regions.

#### Future Research Plans

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

#### Service

Komm continues as coordinator of the Local Helioseismology Comparison Group (LoHCo), and he helped organize the 2007 NSO Workshop #24 on Subsurface and Atmospheric Influences on Solar Activity.

### **John W. Leibacher, Astronomer**

#### Areas of Interest

Helioseismology, Atmospheric Dynamics, Asteroseismology

#### Recent Research Results

Leibacher's recent work has focused on various aspects of helioseismic time-series analyses, including a significant extension to lower frequencies of eigenmode detections, the solar cycle variation of the eigenfrequencies, on which helioseismology is based, new techniques for measuring solar subsurface meridional circulation and its variation with the solar cycle, as well as the variation of the helioseismic signal with altitude in the solar atmosphere.

#### Future Research Plans

Ideas about the observational signature of the convective excitation of  $p$ -mode oscillations are being pursued with data from GONG as well as instruments onboard the SOHO spacecraft with collaborators at the Institut

d'Astrophysique Spatiale (Orsay, France) and the Observatoire de Paris-Meudon, as well as the application of helioseismic techniques to stellar oscillations, in the framework of the CoRoT mission.

#### Service

Leibacher serves as co-editor of the NSO section of the *NOAO/NSO Newsletter*, and as a member of the NSO Scientific Personnel Committee. He has been a mentor to an undergraduate physics student for three of the last six summers. He serves on the Solar Physics Division's summer school program, edits the SPD Resource Directory, and maintains the *SolarNews* WWW site. He is a co-editor of the journal *Solar Physics*.

### **Aimee Norton, Assistant Astronomer**

#### Areas of Interest

Spectropolarimetry, Solar Atmospheric Energy Transport, MHD Waves, Observational Aspects of Solar Dynamo, Instrument Development

#### Recent Research Results

Socas-Navarro & Norton (*ApJ*, 2007, 660, L153) researched the solar oxygen elemental abundance, which has been a point of hot debate recently among observers and theorists whose models of the stellar/solar interior do not match recently observed values in solar-type stars. They advocate a downward revision of the solar oxygen abundance based on spatially resolved observations of the oxygen lines in the solar atmosphere taken with the SPINOR instrument at the Dunn Solar Telescope.

Norton, Petrie & Raouafi (Norton & Raouafi, 2008, NSO Workshop 24, ASP Conf. Series, Vol. 383, 405; Norton, Petrie & Raouafi, in preparation) examine the dynamics of the solar magnetic dipole during the time period of the 1996 solar minimum. Analysis of the solar surface flux distribution and associated coronal geometry using LASCO, EIT and Kitt Peak magnetogram data shows a non-zero tilt angle at all times but does not show that the polar caps have a persistently tilted geometry with respect to the rotational axis.

#### Future Research Plans

Norton has recently taken time-series observations with the NSO Array Camera (NAC) at the McMath Pierce Solar Telescope, sampling half a dozen sunspot umbrae. These observations are the precursor to establishing synoptic observations of short time-scale MHD dynamics utilizing the 1.56 micron wavelength as observed with the NAC. Preliminary results were presented at the IAU Symposia 247 in Venezuela, showing upward propagating magneto-acoustic waves. A more refined analysis technique is being applied to the data in order to invert the Stokes profiles at multiple layers in the atmosphere, allowing for gradients and better fits to asymmetries.

Norton plans to participate in the coordinated efforts to characterize the quiet Sun as part of the International Heliophysical Year "Whole Heliosphere Interval" (10 March 20 – 16 April 2008). She will observe quiet Sun magnetic fields simultaneously in the infrared and visible wavelengths at several locations on the solar disk.

#### Service

Norton, as the Program Scientist for SOLIS, is actively involved in the calibration of SOLIS VSM data and the incorporation of critical data processing code into the pipeline. She is the science contact for the development of the Kitt Peak McMath-Pierce "Sunnel" installation that allows visitors an opportunity to "walk through" the solar interior and atmosphere layers, learning about the dynamic processes of our Sun along the way.

### **Matthew J. Penn, Associate Astronomer**

#### Areas of Interest

Spectropolarimetry, Near-IR Instrumentation, Solar Atmosphere, Oscillations



### Recent Research Results

An analysis of archived sunspot images from the KPVT showed a cyclic oscillation of the sunspot umbral intensity during the solar cycle from 1993-2003, where sunspots were darker on average during solar maximum and brighter during solar minimum. This agreed with infrared spectroscopic studies taken during the past seven years. Results were published in 2007. The velocity, line-depth and line-width KPVT data are also being examined to look for changes in sunspots during the solar cycle. Recently, the NSO Array Camera (NAC) polarization optics obtained full Stokes profiles, and these observations will be repeated when sunspots from the next solar cycle appear.

### Future Research Plans

Penn is currently involved in vector magnetic field observations using the 1565 nm infrared lines from the McMath-Pierce telescope; polarimetry of spectral lines in the 3-5 micron wavelength range will be explored in the near future.

### Service

Penn has recently completed a new polarimeter for use from 1000-2500 nm with the NAC. Future work will involve polarimetry in the 3000-5000 nm wavelength range. Improvements will be made to the NAC scripting language, and the polarization control system will be streamlined. Penn is involved with the ATST development, particularly the IR and coronal aspects of the telescope. Work at the McMath-Pierce telescope with the NAC are intended to develop future science programs for the ATST. Penn is advising a graduate student from the University of Arizona on a project exploring the KPVT spectroscopic data archive. He is now in charge of the NSO summer Research Experiences for Undergraduates (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 Research-Based Science Education (RBSE) and other 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, Penumbral Fine Structure, Vector Polarimetry; Space Weather: Solar Drivers; Chromospheric Filaments and Prominences: Structure

### Recent Research Results

Pevtsov worked with researchers from NSO and other institutions on several studies including the role of magnetic fields in coronal heating, helicity of solar magnetic fields, and statistical properties of coronal bright points. He also continued to work on direct comparison of magnetograms taken by independent instruments.

Statistical study of coronal bright points (CBP) supports the presence of two distinct classes of these features, i.e. those associated with the quiet Sun, and those that can be linked to the “active” Sun. At high latitudes, a number of the quiet Sun’s CBPs shows negative correlation with the sunspot numbers.

### Future Research Plans

A. Pevtsov plans to continue his studies of magnetic and current helicities on the Sun. He will also do research on prominences and Moreton waves.

### Service

In FY 2007, Pevtsov served as Solar Physics Discipline Scientist at NASA Headquarters and as Program Scientist for all NASA solar missions: Hinode, RHESSI, SOHO, SDO, TRACE. He served as a reviewer for four professional publications, *Solar Physics*, *Advances in Space Research*, *Journal of Geophysical Research*, and *Monthly Notices of the Royal*

*Astronomical Society*). In FY 2007, A. Pevtsov taught two on-line undergraduate classes at New Mexico State University. He gave three public lectures: to the summer 2007 participants in the NSO and KPNO REU/RET programs, at the Museum of Space History in Alamogordo, New Mexico, and at the White Sands National Monument Visitor Center.

### **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**

During the past two years, Rimmele has co-authored several papers in refereed astronomical journals: a) “The Evershed Flow: Flow Geometry and Its Temporal Evolution,” Rimmele, T. R. & Marino, J. 2006, *ApJ*, 646, 593; b) “Multi-wavelength Study of Flow Fields in Flaring Super Active Region NOAA 10486,” Deng, N., Xu, Y., Yang, G., Cao, W., Liu, C., Rimmele, T. R., Wang, H., Denker, C., 2006, *ApJ*, 644, 1278; c) “Detection of Opposite Polarities in a Sunspot Light Bridge: Evidence of Low-altitude Magnetic Reconnection,” Bharti, L., Rimmele, T. R., Jain, R., Smartt, R. N., 2007, *MNRAS*, 1674; d) “Solar Atmospheric Oscillations and the Chromospheric Magnetic topology,” Vecchio, A., Cauzzi, G., Reardon, K. P., Janssen, K., Rimmele, T. R., 2007, *A&A*, 461; e) “Adaptive Optics at the Big Bear Solar Observatory: Instrument Description and First Observations,” Denker, C., Tritschler, A., Rimmele, T. R., Richards, K., Hegwer, S. L., Wöger, F., 2007, *PASP*, in press.

Rimmele leads the NSO solar adaptive optics (AO) program. The NSO Multi Conjugate AO system was successfully locked on solar structure and its ability to correct an extended field of view (compared to conventional AO) was demonstrated. This work was published in SPIE proceedings. The ATST activities were published in a number (8) of recent SPIE and COSPAR proceedings. Rimmele gave invited talks at the SOT17 (Tokyo) and COSPAR (Beijing) meetings.

#### **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. He is working with the IBIS team from Arcetri, Italy on understanding the physics of chromospheric dynamics. He will continue to improve the understanding of structure and dynamics of sunspots and test existing MHD models. Due to the extensive commitments to *Service* (see below), Rimmele has very limited time available for research.

#### **Service**

Rimmele is project scientist for the Advanced Technology Solar Telescope Project and principal investigator of the NSO Solar Adaptive Optics Program. He is working closely with the chair of the ATST Science Working Group (T. Berger) to organize and direct the ATST science support effort. He also leads the ATST adaptive optics design and development effort. A recent major milestone was the successful completion of the NSF conducted Preliminary Design Review. Rimmele is also the Dunn Solar Telescope program scientist. In this position he is responsible for all DST instrumentation and telescope upgrade projects and operations. He is directing the Sac Peak technical and operations teams. He supervised recent PhD recipient Jose Marino (NJIT) and currently supervises two post-graduate Research Fellows (F. Wöger and A. Tritschler). Rimmele is Co-I on an MRI-funded project (with PI H. Lin (U. of Hawaii Institute for Astronomy)) to develop an infrared polarimeter for the DST and Solar-C on Haleakalā. He serves as division chair of the Optical Systems for Earth, Air, and Space Technical Group of the Optical Society of America. In that capacity, Rimmele organized a session on laser guide star technology at the Frontier in Optics meeting in Rochester,

NY and participated in the peer review of the technical submissions for the Frontiers in Optics conference. Rimmele chaired the US Steering Committee of the DFG/ NSF Astrophysics Conference in June 2007 in Washington, DC. This conference was the third in a series of research conferences that US and German science funding agencies jointly organize to bring together scientists from the US and Germany with the purpose of exchanging ideas and establishing professional and personal links that will result in joint transatlantic research projects. Rimmele served as a member of the Technical Program Committee for the Adaptive Optics: Analysis and Methods Topical Meeting sponsored by OSA, which was held in June 2007, in Vancouver, British Columbia, Canada. He continues to serve as referee of a number of papers submitted to *ApJ*, *A&A*, *PASP* and *JOSA A*.

### **Clifford Toner, Associate Scientist**

#### **Areas of Interest**

Global and Local Helioseismology, Data Processing and Analysis Techniques

#### **Recent Research Results**

Toner is working on a preprint describing how “copipe,” the GONG angle determination pipeline, works and why it is needed. Other recent research-related activities include porting of the copipe codes to Linux and running tests to compare results from the two platforms (solaris and Linux). He found that there are small differences (a few parts in  $10^{-6}$  to  $\sim 1$  part in  $10^{-5}$ .) Toner recently began working with the SOLIS project ( $\sim 75\%$  FTE).

#### **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 improvements to the numerical behavior in the presence of sharp temperature, density, and velocity gradients. 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. He is computing response functions, which provide a measure of the sensitivity of a spectral feature to given parameters in an atmospheric model, to estimate the heights in the solar atmosphere to which polarization signals in chromospheric lines are sensitive. Comparison of the spatially averaged line profiles of chromospheric lines with calculated profiles from hydrostatic models shows that these lines have a strong red asymmetry in their cores. Even when the observed profiles are compared with spatially averaged profiles calculated through hydrodynamic simulations of the solar convection, this discrepancy remains. Possibly the red asymmetry is the result of acoustic waves steepening into shocks, the same mechanism that gives rise to the well-known K2V phenomenon in the Ca II K line. These waves are numerically suppressed in convection simulations and their contribution would not show up in the spectra calculated from the simulation snapshots. The

observed redshift therefore further supports the notion of a very dynamic nature of the chromosphere. Uitenbroek has obtained observations of the Ca II K line and 854.2 nm IR line at high spatial and spectral resolution in cooperation with Alexandra Tritschler at NSO and will compare these in detail with model simulations to discover the origin of the redshift.

Together with Alexandra Tritschler and Thomas Rimmele at Sac Peak Uitenbroek investigated the contrast in the solar granulation in the spectral G band. Comparing computed contrasts from state-of-the-art numerical MHD simulations with speckle reconstructed images they determined that the computed contrast is up to 50% higher than the observed one, indicating that the simulations are still lacking realism in some aspects.

With Alexandra Tritschler at Sac Peak and Kevin Reardon at Acretri in Florence Uitenbroek used observations of IBIS in the Ca II 854.2 nm line to investigate the nature of a bright filamentary structure near a sunspot umbra. They speculate that this feature may be the result of current dissipation induced by a horizontal discontinuity in the magnetic field which results from convection induced foot point motions.

With Marianne Faurobert and Catherine Grec of the University of Nice Uitenbroek investigated the viability of the so called differential speckle imaging technique by applying this technique to spectra computed from numerical three-dimensional MHD simulations, and determined that it is a viable method to observationally deduce the formation height of spectral lines relative to that of the continuum.

#### Future Research Plans

In the coming year, Uitenbroek plans to continue with the development of his radiative transfer code. It will be used to investigate the formation of chromospheric lines, including their polarization, in newly available MHD simulations that include the chromosphere and transition region. This will show how well the chromospheric thermodynamic conditions as well as the magnetic field can be recovered from for instance polarimetric observations of the Ca II 854.2 nm line with IBIS. The radiative transfer code will also be used to investigate the linear polarization properties of the Na I D lines due to scattering in cooperation with J. Trujillo Bueno (IAC, Spain). And further simulations of the differential speckle interferometry technique will be done with the group in Nice.

#### Service

Uitenbroek serves as the chair of the Telescope Allocation Committee at Sac Peak, and also oversees the science exhibit in the Sunspot Visitor Center. He is the science lead for the Visible-light Broadband Imager (VBI) instrument for the ATST, and the colloquium organizer at Sac Peak. About fifteen different researchers in different institutes, some even outside the field of solar physics, have requested copies of Uitenbroek's transfer code. He actively supports those users with updates and helps running the code. Uitenbroek is also the Co-I on the NSO side of the PAARE proposal to NSF in cooperation with NMSU in Las Cruces. Uitenbroek is Co-I on the IRIS SMEX proposal to be submitted by Lockheed to NASA, and on the SUMI suborbital flight proposal run by MSFC.

## APPENDIX E: FACILITIES AND MAINTENANCE PLAN (FY 2008)

With the commissioning date of the Advanced Technology Solar Telescope at least seven or eight years away, NSO must continue to serve the US solar community with its current facilities and maintain them in a manner that keeps US solar astronomers at the forefront of solar physics. We have already started the ramp down of some aspects of our operations in order to generate ATST support and will continue to do so at an accelerated pace once ATST funding is secured and a commissioning date established. NSO, however, must continue to provide observing facilities and data to the community, as well as push the development of technologies that will enable ATST.

The current budgets for the NSO remain insufficient for optimum utilization of US solar facilities on Sac Peak and Kitt Peak. While there is sufficient funding to carry out essential routine maintenance, there are several major maintenance items that are beyond the range of our normal funding but need to be addressed quickly. What follows are descriptions of each of the prioritized items listed in Table V-11 of Section V-3.3.2 (page 37) broken down by site.

### 1. *NSO Sacramento Peak (NSO/SP)*

Historically, the annual budget for NSO/SP has included approximately \$40K in funds above the normal maintenance program for use on larger “projects.” Typically, some of these funds were saved or carried over to accomplish these projects that were beyond the normal budget. With the continuing rise in building supplies, propane, and electricity, and flat budgets, our discretionary funds have been absorbed into the daily maintenance activities. Some of the following are items that have been deferred numerous times over the past years and will be very difficult or impossible for us to accomplish without supplemental funding. Each of these items has been evaluated with the development of the ATST and the expected closure of Sac Peak in mind, and represents improvements needed in the short term.

- a. **Deformable Mirror (DM) Replacement – Request: \$100K.** The DM at port 4 is approximately 12 years old and deteriorating in optical quality. Actuators near the edge of the DM show large position errors and drift with temperature changes at the DST. The DM cannot be flattened to an acceptable level using the wavefront sensor only. Recently, we had to revive the laser interferometer and implement a procedure that flattens the DM surface using the interferograms. This gives better results but the procedure is complex and without major investment in manpower not practical for daily operations. As a consequence, significant downtime and frequent AO PI involvement are required. The coating of the port 4 DM is also showing significant defects. The DM on port 2 is of a more recent and improved generation and is much more stable. We would replace the DM on port 2 and use the “old” DM for MCAO experiments, for which we currently do not have any dedicated hardware.
- b. **DM Drive Electronics – Request \$100K:** Drive electronics for the port 4 DM.
- c. **DST Storage Area Network (SAN) – Request \$50K:** The highly successful development of two high-order adaptive optics (AO) systems at the DST has generated much interest within the solar community to develop new and upgraded existing instrumentation. Examples of new instruments (post-AO development) include: the Diffraction-Limited

Spectro-Polarimeter (DLSP), the Interferometric Bidimensional Spectrometer (IBIS), and a high-speed g-band camera system. IBIS is scheduled for an upgrade early this year. NSO and HAO are actively developing a new polarimeter (SPINOR) with enhanced capabilities to replace the highly successful but ageing Advanced Stokes Polarimeter (ASP). Other instruments under development for DST deployment include: Facility Infrared Spectro-Polarimeter (FIRS) being developed by the University of Hawaii Institute of Astronomy, and ROSA, an instrument to measure Rapid Oscillations in the Solar Atmosphere being developed by Queen's University, Belfast. ROSA cameras are prototypes of the fast (up larger format) cameras needed for ATST. We are currently near the maximum capacity of our data handling system. The IBIS upgrade will include integration of IBIS into the DST SAN; this will push the system well over capacity. With FIRS and ROSA deployment on the near horizon, we must put resources into upgrading our data handling system now. Our plan is to purchase at least 4 TB of storage and replace the existing DLT storage media with another media, such as USB 2.0-compliant, removable hard drives.

**Update:** This is currently being funded from annual project funds. We currently have \$26K and intend to add another \$15K from new project funds into this effort. We have determined that USB 2.0 will not meet our needs. We have been testing eSATA external hard drives but the results are not comforting thus far. We are presently pricing the hardware to upgrade the SAN and DST data storage capacity and the required network hardware. At the moment, the cost appears to be on the order of \$80K. We are requesting \$50K to add to the funds we currently have.

- d. **Road Replacement – Request: \$150K.** The roads around Sac Peak are in very poor condition, especially the road through housing, which has not been replaced or reconditioned in over 20 years. The current condition of the roads and the harsh weather conditions require a heavier than normal maintenance activity to maintain their usage. Safety and impact on vehicles are also problems.
- e. **Equipment Replacement – Request: \$75K.** The current loader is over 10 years old. It is heavily used, especially for snow removal, and is experiencing more breakdowns and subsequent downtime.
- f. **Vehicle Replacement – Request: \$25K.** Two of our current staff vehicles have over 100K miles and are beginning to experience more maintenance problems. These vehicles are heavily used for transportation of our staff to Tucson, El Paso (airport) and other locations. Frequently, they are driven in very remote parts of the country and at odd hours and conditions where breakdowns could be dangerous.
- g. **Housing Wireless Upgrade – Request: \$8.7K.** Objective: To provide a more stable and upgradeable wireless network to the housing area. This wireless service in housing allows our employees and visitors to access the network at home. Many of them are doing work and official correspondence through this system.
- h. **DST Weather Station – Request: \$2K.** As a result of vandalism and the quality of equipment used, our weather equipment is not working. We request \$2,000 for a

weather station, which would be mounted on the railing just below the turret, as weather readings are better from the turret level.

## **2. NSO Tucson (NSO/T)**

Support for the NSO facilities on Kitt Peak is partially embedded in the NOAO/Kitt Peak budget. Thus, system failures and maintenance at the NSO/Kitt Peak facilities have a direct impact on the call for NOAO/Kitt Peak services for support and maintenance as well as on NSO support to the community. FY 2007 carry over funds will be used this year to address the following deferred maintenance item.

- a. **McMath-Pierce Guider and Tracking Improvements for NSO Array Camera (NAC) – Request \$75K:** An upgrade to a modern control system for guiding will (1) maintain the availability of the telescope as a test-bed for ATST infrared instrumentation and science; and (2) enhance the NAC scientific effectiveness for the community through the implementation of a modern control system that will achieve the full potential for supporting joint observations. The NAC AO system will be relocated in order to accommodate a new tracking system. The system will be a combination of existing hardware and a low-risk motion control system with integrated advanced components and computer. Software development will be assigned to the new NAC/SOLIS scientific programmer with enough budget flexibility to subcontract some software efforts if necessary. The time estimate for completion of the improved guider and tracking system is approximately six months.

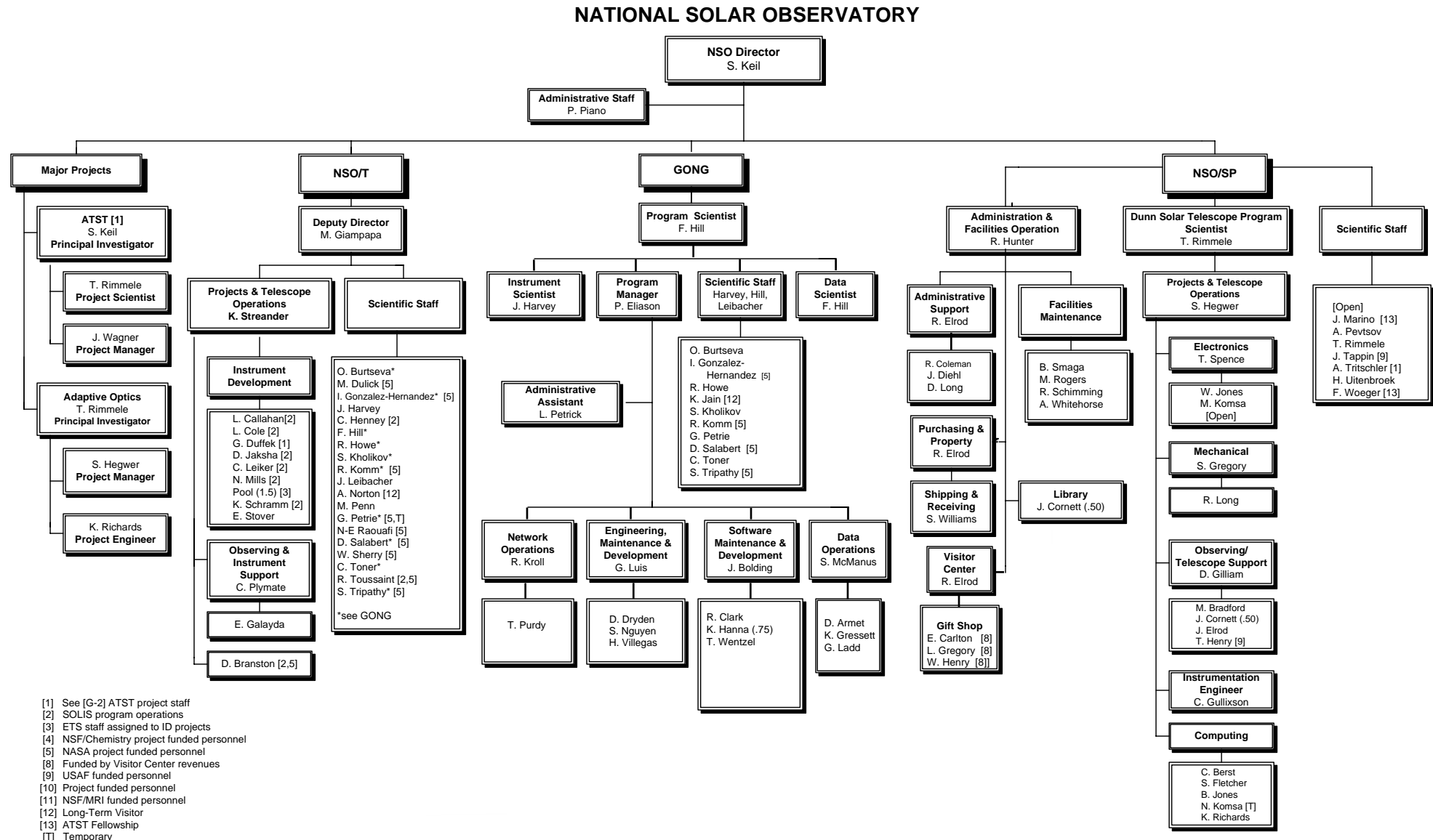
## APPENDIX F: NSO MANAGEMENT

Stephen L. Keil	NSO Director; ATST Project Director
Mark S. Giampapa	NSO Deputy Director; SOLIS Principal Investigator
Thomas R. Rimmele	ATST Project Scientist; Dunn Solar Telescope Program Scientist
Jeremy J. Wagner	ATST Project Manager
John W. Harvey	SOLIS Project Scientist
Aimee A. Norton	SOLIS Program Scientist
Kim V. Streander	Project & Telescope Manager, NSO Kitt Peak
Stephen Hegwer	Project and Telescope Manager, NSO Sacramento Peak
Frank Hill	GONG Program Scientist
Patricia Eliason	GONG Program Manager
Rex Hunter	Facilities & Business Manager, Sacramento Peak

### *NOAO Managers Who Provide NSO Program Support*

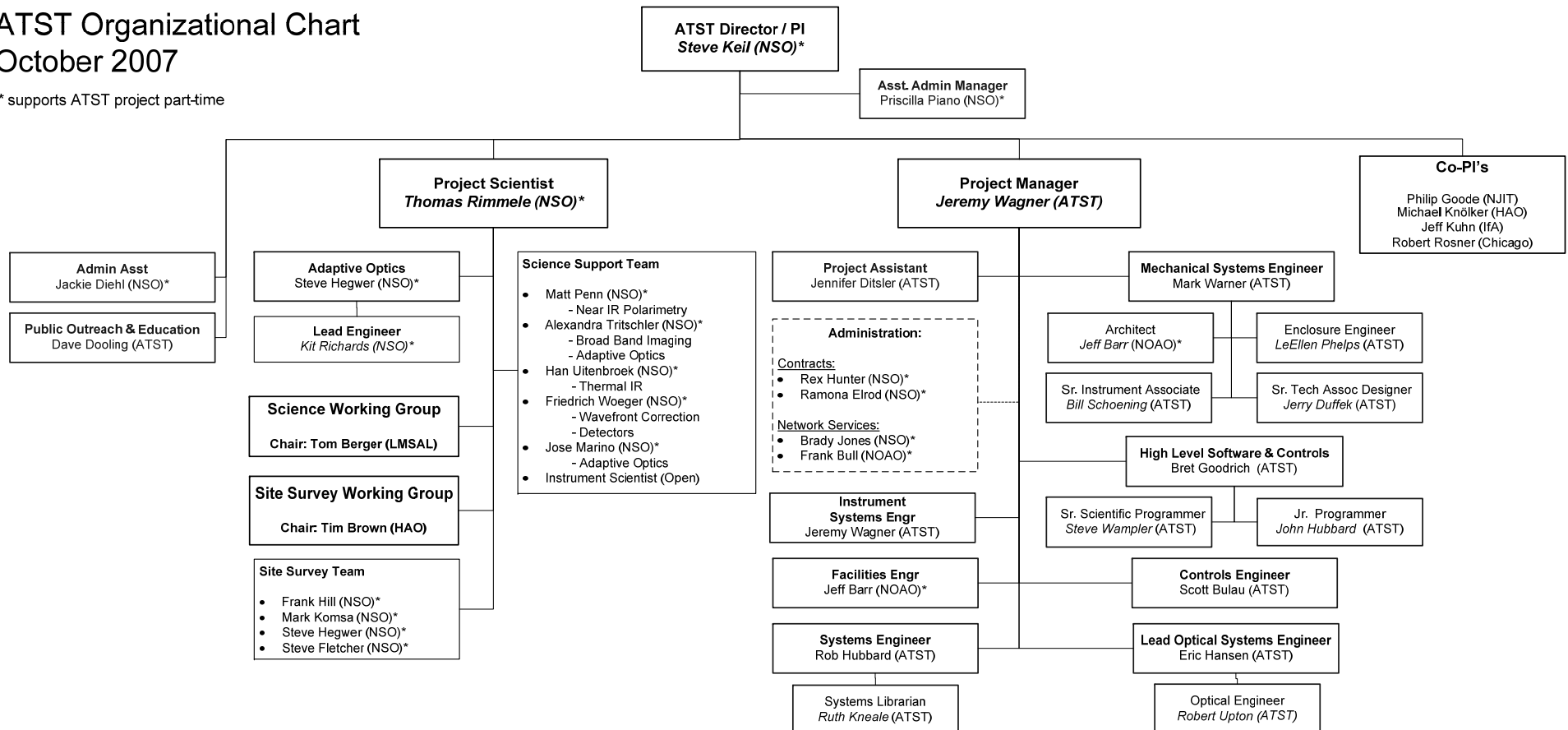
Karen Wilson	Associate Director for Administration and Facilities
Doug Isbell	Associate Director for Public Affairs and Educational Outreach
James Tracy	Controller
Steve Grandi	Manager, Computer Infrastructure Services (CIS)
John Dunlop	Manager, Central Facilities





# ATST Organizational Chart October 2007

\* supports ATST project part-time



## APPENDIX H: ACRONYM GLOSSARY

AASC	Astronomy and Astrophysics Survey Committee
AAS	American Astronomical Society
AFRL	Air Force Research Laboratory
AIS	Advanced Image Slicer
AO	Adaptive Optics
AO76	Adaptive Optics system with 76 degrees of freedom
ARs	Active Regions
ASP	Advanced Stokes Polarimeter
ASWG	ATST Science Working Group
ATI	Advanced Technology Instrumentation (NSF Program)
ATST	Advanced Technology Solar Telescope
AURA	Association of Universities for Research in Astronomy, Inc.
BBSO	Big Bear Solar Observatory
BP	Bright Points
CAMAC	Computer Automated Measurement And Control
CBP	Coronal Bright Points
CCC	Camera Control Computer
CCD	Charged Couple Device
CD-ROM	Compact Disk – Read Only Memory
CDUA	Conservation District Use Application
CfAO	Center for Adaptive Optics
CFD	Computational Fluid Dynamics
CHU	Critical Hardware Upgrade
CME	Coronal Mass Ejection
CNES	Centre National d'Etudes Spatiales
CoDR	Conceptual Design Review
CoMP	Coronal Multichannel Polarimeter (HAO)
CoRoT	CONvection, ROTation and Transits (ESA/CNES space mission)
COPIPE	Camera Offset PIPEline (GONG)
CoSEC	Collaborative Sun-Earth Connection
CSSP	Council of Scientific Society Presidents
CSUN	California State University, Northridge
DASL	Data and Activities for Solar Learning
DHS	Data Handling System
DMAC	Data Management and Analysis Center
D&D	Design and Development
DRD	Design Requirements Document
DSDS	Data Storage & Distribution System
DST	Dunn Solar Telescope
EGSO	European Grid of Solar Observations
EIS	Environmental Impact Statement
EPO	Educational and Public Outreach
ESA	European Space Agency
ESF	Evans Solar Facility
ETH-Zürich	<i>Eidgenössische Technische Hochschule- Zürich</i>
EUV	Extreme Ultraviolet

## APPENDIX H: ACRONYM GLOSSARY

F&A	Facilities & Administration (AURA Fee)
FASR	Frequency Agile Solar Radiotelescope
FDP	Full-Disk Patrol (SOLIS)
FIRS	Facility Infrared Spectro-Polarimeter
FOV	Field of View
FP	Fabry-Perot
FTR	Field Tape Reader
FTS	Fourier Transform Spectrometer
FY	Fiscal Year
GA	Genetic Algorithms
GB	Giga Bytes
GONG	Global Oscillation Network Group
GOLF	Global Oscillations at Low Frequencies
GSFC	Goddard Space Flight Center
GUI	Graphical User Interface
HAO	High Altitude Observatory
HMI	Helioseismic and Magnetic Imager (SDO Instrument)
HSG	Horizontal Spectrograph
HT	Hilltop Telescope
IAC	<i>Instituto de Astrofísica de Canarias</i> (Tenerife, Spain)
IBIS	Interferometric BI-dimensional Spectrometer
ICC	Instrument Computer Control
ICD	Interface Control Document
IFA	Institute for Astronomy (University of Hawaii)
IFU	Integral Field Unit
IHY	International Heliophysical Year
IR	Infrared
IRAF	Image Reduction and Analysis Facility (NOAO)
ISE	Informal Science Education (NSF)
ISOON	Improved Solar Observing Optical Network
ISS	Integrated Sunlight Spectrometer (SOLIS)
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
LCVR	Liquid Crystal Variable Retarder
LTE	Local Thermal Equilibrium
LWS	Living With a Star (NASA)
LoHCo	Local Helioseismology Comparison Group
LTO	Linear Tape-Open
McMP	McMath-Pierce (Solar Telescope)
MDI	Michelson Doppler Imager
MEMS	Micro-Electro-Mechanical System
MHD	Magnetohydrodynamic
MKIR	Mauna Kea Infrared

## APPENDIX H: ACRONYM GLOSSARY

MOU	Memorandum of Understanding
MREFC	Major Research Equipment Facilities Construction
MRI	Major Research Instrumentation (NSF)
NAC	NSO Array Camera
NAOJ	National Astronomical Observatory of Japan
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NDSC	Network for the Detection of Stratospheric Change
NEO	Near-Earth Object
NHPA	National Historic Preservation Act
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
NPFC	Non-Potential Field Calculation
NRC	National Research Council
NSB	National Science Board (NSF)
NSF	National Science Foundation
NSF/AST	National Science Foundation, Division of Astronomical Sciences
NSF/ATI	National Science Foundation, Advanced Technology and Instrumentation
NSF/ATM	National Science Foundation, Division of Atmospheric Sciences
NSO	National Solar Observatory
NSO/SP	National Solar Observatory Sacramento Peak
NSO/T	National Solar Observatory Tucson
OMB	Office of Management and Budget
OSPAN	Optical Solar Patrol Network (formerly ISOON)
PAEO	Public Affairs and Educational Outreach
PCA	Principal Component Analysis
PDR	Preliminary Design Review
PMCS	Project Management Control System
PSF	Point Spread Function
QSA	Quasi-static Alignment
QUB	Queen's University, Belfast (Ireland)
RAID	Redundant Array of Independent Disks
RASL	Research in Active Solar Longitudes
RBSE	Research-Based Science Education
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RFQ	Request for Quote
RFP	Request for Proposal
ROSA	Rapid Oscillations in the Solar Atmosphere
SAN	Storage Area Network
SATA	Serial Advanced Technology Attachment
SCB	Sequential Chromospheric Brightening
SCSI	Small Computer System Interface
SCOPE	Southwest Consortium of Observatories for Public Education

## APPENDIX H: ACRONYM GLOSSARY

SDO	Solar Dynamics Observatory
SDR	Systems Design Review
SH	Spherical Harmonic
SOHO	Solar and Heliospheric Observatory
SOI/MDI	Solar Oscillations Investigations/Michelson Doppler Imager (SOHO)
SOLIS	Synoptic Optical Long-term Investigations of the Sun
SOT	Solar Optical Telescope (Hinode)
SPD	Solar Physics Division
SPINOR	Spectropolarimeter for Infrared and Optical Regions
SRA	Summer Research Assistant
SRD	Science Requirements Document
SSB	Space Science Board
STEREO	Solar TERrestrial RELations Observatory
SXT	Soft X-ray Telescope ( <i>Yohkoh</i> )
TAC	Telescope Allocation Committee
TB	Tera Bytes
TCS	Telescope Control System
TL	Transequatorial Loop
TLRBSE	Teacher Leaders in Research-Based Science Education
TON	Taiwan Oscillation Network
TRACE	Transition Region and Coronal Explorer
UBF	Universal Birefringent
UCSD	University of California, San Diego
UV	Ultraviolet
VMICAL	Velocity-Modulation-Magnetogram Intensity Calibration (GONG)
VBI	Visible-light Broadband Imager (ATST)
VC	Virtual Camera
VMG	Vector Magnetograph
VSM	Vector Spectromagnetograph (SOLIS)
VSO	Virtual Solar Observatory
VVWG	VSM Vector Working Group (SOLIS)
WBS	Work Breakdown Structure
WFS	Wavefront Sensor
WWW	World Wide Web
<i>Yohkoh</i>	“Sunbeam,” Satellite project of the Japanese Institute of Space and Astronautical Sciences
ZIMPOL	Zürich IMaging POLarimeter