ANNUAL PROGRAM PLAN OF THE NATIONAL SOLAR OBSERVATORY **FY 2009**





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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, developing a diverse workforce, 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 undergraduate and graduate students, helping develop classroom activities, working with teachers, mentoring high school students;
- promoting diversity in the solar work force;
- 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;
- Establishing partners for the operation of the Global Oscillation Network Group (GONG) telescopes;
- Establishing programs that will increase diversity in the solar workforce
- 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 2009 program outlined in this plan will continue to advance these strategic objectives. The plan presents in detail what NSO proposes to accomplish in FY 2009 with the \$11,632K originally 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 addresses how NSO would respond to reduction from this amount to the FY 2007 number of \$9,971K, a reduction of \$1,661K. The plan also discusses how the 2009 program supports the strategic goals of solar physics; planning for NSO in the ATST era; how NSO will transition its programs, taking into account the advice of the Senior Review; and 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. A plan for increasing the diversity of the NSO workforce as well as the solar physics work force is also discussed. 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.

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2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
	ATST Des	sign 🚤			ATST Construction			\leq	Operations		
	McMat	n-Pierce S	Solar Tele	scope, F	TS						
		Dunn So	lar Teles	соре					1		
	-							/			
	ES	F Partnei	Support	ed Opera	tions		-				
1											
\langle	SO	LIS	/		Sy	noptic Pr	ograms a	& Networ	k		
	GC	NG ++		>	Assume	s >50% e:	xternal fu	nding for	GONG		
	Digital Library - Virtual Solar Observatory										
a.											
						Harrison I.					
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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 2009 to facilitate a smooth transition to construction in either late FY 2009 or early FY 2010. The entire NSO road map is keyed to the start of ATST construction before the end of 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. 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 nearreal-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 <u>http://atst.nso.edu/.</u>

The ATST was first proposed to NSF as a design and development Review of the project in 2001. proposal showed that the community had developed an excellent science case for ATST and design and development the (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, successful а 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

Table 1.1.1	ATST Science Working Group						
	. 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						
Roberto Casini	High Altitude Observatory						
Gianna Cauzzi	Arcetri Observatory, Italy						
Manuel Collados-Vera	Instituto de Astrofisica 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 Astrofisica de Andalucia, 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						

submitting ATST for funding, moving it from readiness into the approval phase. NSF and the ATST project are now completing a final Environmental Impact Statement (EIS) for the proposed construction site on Maui and are making preparations for an NSF conducted final baseline review (FBR) scheduled for early March 2009.

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 site infrastructure, enclosure, telescope mount assembly and data handling system software. The ATST project team continues to draw from a broad range of resources, which includes 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-tocost "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 industry and from 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.

TABLE 1.1-2. ATST Engineering Responsibilities							
Systems Engineering	Eric Hansen						
	Rob Hubbard						
Telescope Assembly	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						
Wavefront Correction	Thomas Rimmele						
	Steve Hegwer						
	Kit Richards						
Instrument Systems	David Elmore						
	Jeremy Wagner						
	Rob Hubbard						
High-Level Controls and Software	Bret Goodrich						
	Steve Wampler						
Enclosure	Mark Warner						
	LeEllen Phelps						
Support Facilities (includes infrastructure items)	Jeff Barr						

1.1.2.1 Current Design Activities

Current design activities include producing mechanical and optical layouts for the transfer optics; finalizing 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 and conducting performance lab, updates based upon the Haleakalā site testing data. The current design is The design shown in Figure 1.1-1. includes the simplified one-level coudé instrument area and feed arrangement. The feed for instrumentation associated



Figure 1.1-1. Current ATST facility design.

with this is more compact and simpler to direct to multiple instrument stations.

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).
- 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 2010 at the earliest. If a delay beyond 2010 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 2010.

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 Halekalā 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 proposed 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.

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. Additional NHPA Section 106 meetings were held on Maui in June and August 2008. The final EIS document is currently being prepared.



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

1.1.5 Plans

During 2010, it is anticipated that the ATST project will transition from design to construction phase. In the near-term, preliminary design efforts, site infrastructure and permitting 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, commissioning (IT&C) planning and staffing, and operations 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 2010 construction start, has calendar year 2016 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 2010. 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 are applied to the construction project and the cost estimates are revised accordingly as OMB factors are updated and made available to the project. 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)										
										Grand
	Fiscal Year	2010	2011	2012	2013	2014	2015	2016	2017	Total
1.2.1	Project Management	1,384	4,193	8,021	5,943	7,134	6,787	3,008	11,761	48,232
1.2.2	Systems Engineering	408	422	437	452	468	484	501	389	3,686
1.2.3	Telescope Systems	28,478	40,874	67,108	22,669	12,251	9,322	1,690	1,290	183,682
1.2.4	Systems Integration & Testing	0	0	0	0	1,329	3,553	4,841	3,315	13,038
1.2.5	Science Support	196	203	210	326	337	378	391	327	2,366
1.2.8	Support Services	1,045	1,650	2,003	1,136	1,116	1,169	913	880	9,913
	TOTAL	31,511	47,342	77,779	30,526	22,635	21,693	11,344	17,963	260,793



Figure 1.1-4. ATST construction funding profile.

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

Due to flat budgets and additional EIS work, the project had a shortfall of approximately \$700K in FY 2008. NSF managed to cover the shortfall with additional funds late in the FY. Given the flat budget projections for at least the first half of FY 2009, the same situation may present itself again.

To maintain the project team, support the on-going EIS process, Special Use Permit (SUP) development with the National Park Service (NPS), the up-coming Conservation District Use Application (CDUA) permitting process, instrumentation development at partner institutions, and perform recommended risk mitigation studies with industry, NSO is requesting additional funding to the projected ATST FY 2009 budget. NSO is requesting \$2.090M for FY 2009 to support the project team's payroll and non-payroll requirements. An additional \$0.660M is requested to support the on-going EIS process, CDUA process, and the Special Use Permit development with the NPS. It is estimated at this writing that the SUP development will require additional road, viewshed, and visitor experience studies at a cost of \$150K. In addition, NPS staff required for the SUP development will cost approximately \$250K. NSO is requesting \$0.197M to support preparations for the NSF conducted Final Design Review (FDR) (i.e., cost updates, Project Management Control System (PMCS) development, etc.) scheduled for March 2009. NSO is also requesting an additional \$3.110M to fund PDR and SDR review committee recommended risk-reduction work, prototyping and design feasibility and cost analysis studies. In addition to the required items above, flat funding over the past two years has resulted in the loss of 4.5 positions. These lost positions include an optical engineer, optomechanical engineer, software engineer, senior mechanical engineer and a mechanical engineer. Restoration of all or any one of these positions would increase the project's effectiveness in meeting the requirements of the MREFC process and preparation for construction. In addition, review committees have recommended that a project contracts officer be added to the team in advance of bid package preparation. The cost of restoring the lost positions plus the addition of a contracts officer in mid FY 2009 to prepare for construction is \$575K.

This budget request of \$6.310M total will permit timely completion of the EIS on Maui, development of the SUP with the NPS, as well as staffing and retention of the full engineering team needed to bring the ATST design through final systems design review and readiness for construction. Preparation for the NSF conducted FDR scheduled for March 2009 will require contracted PMCS development work estimated at \$197K. The additional funding will also permit implementation of critical risk reduction contracts with vendors. The risk-reduction efforts include completion of the site architectural and engineering work and the

foundation design (\$300K) with industry. Other recommended work includes AO deformable mirror prototyping (\$400K) and wavefront sensor camera development (\$400K), and further software and controls development (e.g., Common Services). 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 considerable cost. The additional costs for development of an SUP with the NPS are an added burden this coming year. Note that the cost of the EIS process continues to severely limit the number and scope of the risk mitigation studies and prototyping that the project can initiate in-house and pursue with industry.

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). This work 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 this work 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 (MCAO) and an advanced AO system for the ATST. Multi-conjugate adaptive optics is a technique that provides real-time diffraction-limited imaging over an extended field-of-view (FOV). The development of MCAO for existing solar telescopes and, in particular, for the next generation large-aperture solar telescopes is thus a top priority. The Sun is an ideal object for the development of MCAO since solar structure provides "multiple guide stars" in any desired configuration. During FY 2005, a first successful MCAO engineering run was performed at the DST. Different algorithms for controlling the two deformable mirrors (DMs) 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. However, further development is needed before operational solar MCAO can be implemented at future large-aperture solar telescopes such as the ATST. MCAO development must progress beyond these initial proof-of-concept experiments and should include laboratory experiments and on-sky demonstrations under controlled or well characterized conditions, as well as quantitative performance analysis and comparison to model predictions.

In FY 2008, a dedicated MCAO bench was implemented at the DST with the goal of developing wellcharacterized, operational MCAO. The MCAO system uses two deformable mirrors conjugated to the telescope entrance pupil and a layer in the upper atmosphere, respectively. DM2 can be placed at conjugates ranging from 2 km to 10 km altitude. For our initial experiments, staged approach is used in which the 97 actuator, 76 subaperture correlating Shack-Hartmann solar adaptive optics system normally operated at the DST is followed by the second DM and the tomographic wavefront sensor, which uses three "solar guide stars". Modal reconstruction algorithms were used for both DMs. The MCAO system was successfully and stably locked on artificial objects (slides), for which turbulence screens are generated directly in front of the DMs, as well as solar structure. The height of the upper conjugate DM was varied between 2 km and 7 km and strictly simultaneous images after the pupil DM and after the upper layer DM were recorded. Comparing these images allows us to evaluate the performance of the MCAO stage and directly compare to the conventional AO. In addition, wavefront sensor telemetry data for closed and open loop were recorded. Jose Marino, now at the University of Florida as an ATST fellow, has produced MCAO reconstructors as well as performance models for the DST MCAO. These models can be compared to the actual achieved system performance. Initial results of the MCAO work have been presented at the Advanced Maui Optical and Space Surveillance Technologies 2008 (AMOS08) conference.

The MCAO development is done in close collaboration with the University of Florida and the Kiepenheuer Institute (KIS) in Freiburg, Germany. Two KIS graduate students spent several months at NSO in FY 2008 to actively participate in the MCAO development and experiments. This collaboration will continue into FY 2009 and beyond. Additional MCAO runs at the DST are already scheduled and KIS students and senior personnel, as well as Jose Marino, will participate. During these upcoming engineering runs, a global reconstruction algorithm will be implemented that promises to provide better performance. In addition, the number of guide stars will be increased.

The ATST will require an AO system that has an order of magnitude more subapertures and actuators compared to the AO76 currently operating at the DST. In order to mitigate the development risk, NSO is partnering with the New Jersey Institute of Technology/Big Bear Solar Observatory (NJIT/BBSO) in the development of a high-order AO system for the New Solar Telescope (NST). The system will have 300-400 degrees of freedom and hence can be regarded as a natural intermediate step towards the ATST AO. In fact, a substantial amount of the software and hardware development involved with the NST AO will be directly portable to the ATST AO. A proposal for the NST AO development has been submitted to the NSF-ATI program with T. Rimmele as the PI. If successful, the three-year development effort would start in FY 2009.

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 FY 2009. 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.
- Stereoscopic High-speed Zeeman Magnetograph (SHAZAM), in collaboration with the Southwest Research Institute (SWRI).

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 $2K \times 2K$ 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 NSO/HAO program that upgrades the previous Advanced Stokes Polarimeter (ASP) at the Dunn Solar Telescope. The ASP has been the premier solar research spectro-polarimeter for the last decade. The ASP wavelength range, however, was restricted to the visible, limiting its ability to sample new solar diagnostics. 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 is integrated into the DST control and data handling systems as opposed to the stand-alone ASP system.

SPINOR is the primary DST research spectro-polarimeter, providing access to spectrum lines across the visible and near-infrared spectrum not accessible to other facility spectro-polarimeters—lines often previously unused for solar diagnostics. SPINOR also provides the capability of combining up to three diverse spectral ranges into a single observation.

Software control of SPINOR, combined with the DST control and data handling systems, has been demonstrated in 2008. Engineering and staff science observing runs are on-going to add a SPINOR interface to the DST camera control system.

2.1.3 Facility Infrared Spectropolarimeter (FIRS)

FIRS 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 instrument now resides on port-4 of the DST and is configured to collect science data at .6302 and 1.56 microns. The addition of a high-resolution optical feed is currently in progress. The remaining major tasks required to bring FIRS to a facility class user instrument include integration to the DST data handling system, implementation of required common services functions, completion of the operators manual, and providing observer training.

The NSO is contributing mechanical design work and manufacturing, and assisting with electronic and optical 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 α diagnostics of electron beams (timescales 0.1 second).
- Radiative hydrodynamics of flares.
- Magnetic field changes at high cadence.

The ROSA commissioning run at the DST was successfully completed in August 2008. Additional observing runs are expected to continue in the first quarter of 2009.

2.1.5 DST Critical Hardware Upgrade (CHU)

Given the finite time frame for DST operations, replacement and upgrades of hardware and software are limited to the necessary minimum. The 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. Approximately 90% of this effort is completed.

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 now routinely obtains images and spectroscopy from 1,000 to 5,000 nm, and polarization data in the 1,000 to 2,200 nm window. The NAC has replaced the aging NSO Near-Infrared Magnetograph (NIM) instrument.

In 2008, the NAC instrument obtained science data at several wavelengths from 1200 nm through 4666 nm, including short-exposure high-resolution granulation images from 1000 to 2200 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)

The telescope control system (TCS) for the McMath-Pierce telescope is antiquated and in need of an upgrade for the telescope to remain competitive and maintainable. Budget constraints prohibited the full upgrade of the TCS, and a more cost-effective solution was needed that would be consistent with future decommissioning as outlined in the Senior Review.

An economical solution of software emulation has been implemented that addresses a key aspect of the TCS reliability problems: the PDP 11/73 control computer (PDP) and peripherals. Because of their age, the system disks and the nine-track tape drives attached to the PDP were prone to failure, and spares were becoming increasingly scarce. The CAMAC crates attached to the TCS computer via a Kinetic Systems 2061 Parallel Data Highway were not replaced as there is a sufficient supply of spare parts. However, from the standpoint of increasing the overall reliability of the TCS, this subsystem should be next on the list for upgrade, should budget and other considerations permit.

The emulation software is run in Linux on a generic PC, with a garden variety multi-port serial card. The system disk and tape drive are emulated as files, so disk backup and tape data maintenance now simply consist of file copy operations (such as ftp over the ethernet) in Linux. The existing qbus backplane was used to house the qbus adapter card for the data highway. The only drawback to the emulation solution was that a special-purpose PCI-to-qbus adapter card (BCI-2104) was needed to interface to the Kinetic Systems qbus card. The drawback was mitigated by purchasing spares. This solution had the distinct advantages of being

the most economical, flexible and maintainable, and one of the easiest to implement. The total cost was \$30K in hardware and required three months for design, implementation, and testing.

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, two-axis translation stage. Four limb sensors mounted at 90° intervals will feed limbposition 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 2D 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. The possibility of developing a higher-order adaptive optics system for the McMP has been discussed with collaborators at California State University-Northridge but that project would proceed only if grant funding becomes available.

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 ~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) will need to be placed on the optical table situated above the main spectrograph; thus a new adaptive optics bench has been developed and is located below the optical table. The final design, programming, construction and implementation of the guider, are planned for 2009.

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 which has been built at the McMath-Pierce.

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 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 6.25×8 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 ~1.2 m × 0.3 m × 0.3 m box that mounts in the optical beam between the current AO system and spectrograph slit.

The IFU was tested on the main spectrograph at the McMath-Pierce telescope during 2008; unfortunately, the mirror alignment hardware for the image slicing mirror was not working properly and needed to be rebuilt. Otherwise the device worked well. There are plans for the IFU to become a user instrument at Kitt Peak in 2009.

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 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, observations of magnetic reconnection in the chromosphere, wave propagation into the chromosphere and chromospheric acoustic shocks and their dependence on the magnetic topology, and chromospheric magnetic field measurements of "quiet Sun" flux tubes. The DST with AO and its state-of-the-art instrumentation is rigorously supporting space missions, such as HINODE, for which a new operational concept, the HINODE service mode, was implemented.

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 microns 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 McMath-Pierce is currently operating with an AO system optimized for IR wavelengths, and a new largeformat IR array detector, the NSO Array Camera (NAC). Currently science projects for which the McMP is uniquely qualified are being run at the telescope, including spectroscopy beyond 2200 nm, and highresolution imaging between 1000 nm and 5000 nm, where the large aperture of the McMP facilitates rapid exposures at those wavelengths. The main new project idea is to develop polarization in the 3000-5000 nm wavelength range, which again is not possible at any other solar telescope currently operating.

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 are supported by 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 FY 2009 SOLIS program plan emphasizes the continued daily acquisition of research-grade data. With the highly publicized delay of the vector spectromagnetograph (VSM) vector magnetogram release, the data that are taken, calibrated and archived daily are often overlooked. SOLIS will continue to provide, as it has done successfully in FY 2008, synoptic full-disk photospheric 630.2 nm and chromospheric 854.2 nm longitudinal magnetograms and their subsequent Carrington Rotation maps. In addition, the numerous integrated sunlight spectrometer (ISS) spectra and derived line parameters will continue to be observed, calibrated and provided on-line for the astronomical community for "Sun-as-a-star" studies.

With the removal of the polarization fringes in the VSM vector data, the SOLIS team will work towards confirming the accuracy of the inversion code results. Once the robustness of the vector data inversion is verified, the code will be integrated into the automated pipeline. The vector data will then be made available to the community online starting with current, daily observed data. Time permitting, past data will be reprocessed and supplied to the community.

After the inversion code is successfully embedded into the automated pipeline and vector data are provided for current, daily observations, the replacement of the old Rockwell cameras with the new Sarnoff cameras will begin. Although the Sarnoff cameras have been characterized, and some initial effort has gone into readying the data handling system for the new cameras, the team has delayed camera replacement in order to release the vector data to the solar community, which is the top priority.

In FY 2009, fast scans of regions likely to flare will be implemented into the VSM observing routine. A fastscan archive will be created so that the data are easily available to outside users. This item was originally on the FY 2008 plan, but the delay of the start of Solar Cycle 24, with little to no sunspot activity, necessitated the delay of the fast-scan program.

The SOLIS team will assemble and install an extinction monitor to provide atmospheric line-of-sight conditions for the ISS instrument. In FY 2008, an iodine cell was purchased and ordered for the extinction monitor. Both the cell and the monitor should be tested early in FY 2009 with calibration and installation to follow. In addition, FY 2009 should witness the completion of the VSM and full-disk patrol (FDP) guider. Completion of the optical alignment of the FDP in FY 2008 enables the instrument to be mounted on the Kitt Peak SOLIS tower late in calendar year 2009.

In regards to software, operating system upgrades are necessary in order to assure that machines are current, but can operate with backward compatibility. Centos, Java and CORBA upgrades on machines will be carried out as appropriate.

Proposed science for FY 2009 includes a characterization of magnetic fields in the canopy fields using 854.2 nm data, the isolation of changes in the photospheric magnetic field before and after the flare events using the fast-scan data, the use of VSM chromospheric field distribution to test standard force-free extrapolation models, the integration of VSM vector photospheric and STEREO data to calculate and compare energy budgets for coronal fields and coronal mass ejections, and finally, assisting SDO/HMI by providing VSM data for comparison of vector field parameters and/or initialization of inversion process if SDO launches during calendar year 2009.

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 1024×1024 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 has entered into a partnership with the US Air Force Weather Agency (AFWA) to provide data for the AFWA Space Weather squadron. AFWA will fund the installation of an H α imaging system that will be placed on the existing optical table in the GONG shelters, and will use the same light feed. The images will be full disk with a format of 2048 × 2048 pixels, and a spectral passband of 0.4 Å. The H α data will be acquired once per minute at each site and the time of acquisition will be staggered by 20 seconds at adjacent

sites so that the network could potentially acquire one image every 20 seconds. The data will be processed and returned to Tucson within one minute of acquisition. AFWA will pull the data from Tucson to its forecast center in Omaha, Nebraska. This data set will be valuable for high-cadence studies of variations in the chromosphere, as well as for space weather forecasts.

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 spinup 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 is developing a system for measuring vector magnetic fields in prominence. The Prominence Magnetometer (PROMAG) will use the 48 cm coronagraph as a light feed. HAO is providing their own engineering and operations support. The first engineering run of PROMAG occurred in summer 2008. Additional engineering runs are planned for 2009.

1.2.2 Hilltop Solar Facility

NSO no longer operates telescopes in the Hilltop Solar Facility. The patrol programs have been replaced by the Optical Solar Patrol Network (OSPAN) and SOLIS. The Hilltop houses a coelostat that feeds an optical bench currently used for testing narrow-band filter systems and other instruments.

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 8.3 million science data files have been distributed to about 9,000 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 disk 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 data sets

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 80,000 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 2009							
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 Sola	r Telescope McMPE	= McMath-Pierce East Auxiliary Telescope					
Instrument Telescope Comments/Description							
NSO/Sacramento Peak – OPTICAL IMAGING & SPECTROSCOPY							
High-Order Adaptive Optics	DST	60 - /0-mode correction					
Interferometric Bidimensional Spectrometer (IBIS)	DST	Spectroscopy – Polarimetry, 20 mA 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 ≤ 40,000, 4200 - 7000 Å					
Horizontal Spectrograph	DST	R <u><</u> 500,000, 300 nm - 2.5 μm					
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies					
Littrow Spectrograph	ESF	$R \le 1,000,000, 300 \text{ nm} - 2.5 \ \mu\text{m}$					
Various CCD Cameras	DST	380 - 1083 nm; Formats: 256×256 to $2K \times 2K$					
Correlation Tracker	DST	Tip/tilt correction					
40-cm Coronagraph	ESF	300 nm – 2.5 μm					
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å					
Ha Video	HT	Hα full-disk					
NSO/Sacramento Peak – IR IMAGING	& SPECTROSCOPY						
Horizontal Spectrograph	DST	High-resolution 1- 2.5 μ m spectroscopy/polarimetry, R \leq 300,000					
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 µm spectroscopy/polarimetry					
NSO/Kitt Peak – IR IMAGING & SPECTROSCOPY							
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	$0.32 - 12 \ \mu m, R \le 10^6$					
1-m Fourier Transform Spectrometer (FTS)	McMP	2200 Å to 18 μm, R <u><</u> 600,000					
NSO Array Camera (NAC)	McMP	1 - 5 $\mu m,1024\times1024,direct$ imaging, and full Stokes polarimetry from 1- 2.2 μm					
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	$380 - 1083 \text{ nm}, \text{R} \le 10^5$					
Image Stabilizer	McMP	Solar, planetary or stellar use to 7 th magnitude for use with the vertical or stellar spectrograph					
Wide-Field Imager	McME	Astrometry/Photometry, 6 arcmin field					
NSO/GONG – GLOBAL, SIX-SITE, HELIOSEISMOLOGY NETWORK							
Helioseismometer & Magnetograph	California, Hawaiʻi, 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. In late FY 2008, NSO started a Broadening Participation initiative to expand among African American, Hispanic, and Native American populations awareness of the need for solar physics research and the potential for careers in the field. This will include expanded outreach through established education and professional venues and direct contacts with minority-serving schools in the vicinities of Tucson and Sunspot (Native American and Hispanic) and Huntsville, Alabama, and Nashville, Tennessee (Aftican American). Details are in a separate plan to be filed by AURA.

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, two supported by NASA programs including Living with a Star and STEREO, and one 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 completed his PhD in adaptive optics in 2007 with Thomas Rimmele as his advisor. Lucia Kleint from ETH in Zürich spent several months in Sunspot in 2007 to obtain data for her Master's thesis, and Brian Harker of Utah State University,

with K. S. Balasubramaniam as his advisor, defended his PhD thesis on 02 December 2008 and will start his appointment as a postdoctoral research fellow at NSO/Tucson in January 2009, supported by a NASA SR&T grant.

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 composed 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 middle and 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 their respective institutions 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. Each summer since 2006, NSO, as a joint effort with the University of Arizona, has 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 2009.

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 2009. 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 2009, and be include in International Year of Astronomy (IYA) activities. It will develop classroom and temporary museum exhibit activities relating to the 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 2009 with a grant from the New Mexico Tourism Department. *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). 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. This is becoming an expanded effort, with initial talks with the University of Florida, to refine questions and to develop the surveys within Federal guidelines.

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 2006 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. An announcement about the program was distributed widely and included information on opportunities for collaborations with NSO scientific staff. Thomas Schad, a former (2006) NSO/REU student, was 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 whitelight image of the Sun from a heliostat outside the Visitor Center to a screen inside the center. In 2009, 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 α and Ca II K filters, will be comounted. 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 (this has been delayed 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, handson units, and models of the Sun and of a sunspot. As a pathfinder for this exhibit, NSO will develop classroom activities to teach junior high and high school students about solar magnetism. This will include a combination of hands-on activities for students and demonstrations that would be conducted by teachers or an NSO officer. These activities will evolve into the educational activities and public information that would accompany a museum exhibit. Additional exhibit materials include new display panels for the Dunn Solar Telescope lobby and the Visitor Center to highlight current observing programs at Sunspot. For the International Year of Astronomy, NSO is investigating the development of two types of spectrohelisocopes, 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. In 2008, expansion across the state was developed with design of "Water in the Desert" markers that will be placed at state parks and other locations that, on the scale of the model, would be in the Kuiper Belt or the Oort Cloud where water is as sparse as in the desert. The State of New Mexico allocated \$75K through its capital funding program for the project, and in 2008 signed a memorandum of understanding to proceed with construction. Funding was received in December 2008 and will allow use of the model as NSO's contribution to the IYA. This required a redesign of the model and deferred the interior fitting of the Sun until additional funding is available. The model will include four new 6 × 8-foot graphics panels: "Our Sun from the Inside Out" (95% complete in 2008), "Sizing Up Your Solar System" (completed in 2007), "One Star Among Many" (50% complete in 2008), and "A Map of the Universe" (98% complete in 2008). Components of this exhibit were used in a temporary exhibit on the Sun at the National Atomic Museum (now the National Museum of Nuclear Science and History), in Albuquerque, March-September 2007, and will continue to be used in fusion education presentations by the museum. NSO and the museum are exploring Sun-related exhibit panels that could be derived from existing or planned NSO materials. 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. These were expanded during 2008 and the models introduced to the public during the Solar Physics Division meeting in Fort Lauderdale in May 2008. An interesting finding about fiber arts was made during participation in a public exhibit at the Space Explorer's Education days (SEED) event at the space museum in Alamogordo.

NSO has delayed investigating the potential for building an ATST Visitor Center at an appropriate location on Maui pending completion of cultural impact hearings because of possible local sensitivities over the issue. There are plans to meet with outreach counterparts from the University of Hawai'i Institute for Astronomy, US 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, was refined during 2008. Completion was postponed because of anticipated design changes to ATST leading the November 2008 systems design reviews. A National Leadership Briefing package was developed during FY 2008, initially for presentation to members of the US Senate and House of Representatives and their staff. It was broadened for distribution to community leaders and the media. In it, 18 pages make the case for ATST and six review the principal partners.

Video products. In late 2007, NSO produced a 7-minute video providing an introduction to ATST. It has been used by Maui Community College on its campus TV system where it was well-received. Following comments during the AURA Members' Meeting in April 2008, production of a new version was started. This will include

interviews with scientists and new animations. NSO also is starting work on a video that will have female scientists, engineers, and staff talk about their careers in solar physics.

Web-Based Outreach. Stories from the quarterly *NOAO/NSO Newsletter* were added to the NSO news section online. 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 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, Mark Giampapa, serves as site director for Tucson and oversees operations there as well as serving 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, Thomas Rimmele, leads and oversees telescope operations and instrument projects and also serves as ATST project scientist. The DST project and telescope manager, Steve Hegwer, 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, Rex Hunter, who is responsible for buildings and grounds, administration and business functions. The DST program scientist and the support facilities and business manager report directly to the NSO 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 with Priscilla Piano as administrative manager. McMath-Pierce operations and projects are led by a telescope scientist, Matt Penn, who reports to the Deputy Director. A project and telescope manager, Kim Streander, and the SOLIS

program scientist, Aimee Norton, also report to the Deputy Director. NSO shares support personnel with Kitt Peak National Observatory (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, Frank Hill. A program manager, Pat Eliason, 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 NSO Director currently serves as ATST Director. A project manager, Jeremy Wagner, and project scientist, Thomas Rimmele, report to the Director. The ATST staff reside in Tucson and at 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 high-level organizational chart is shown in Figure V-1. Detailed charts are shown in Appendix F. 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 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 National Solar Observatory (NSO) FY 2009 program relevant to the Senior Review recommendations include:

- Continued development of the 4-meter Advanced Technology Solar Telescope (ATST) on behalf of, and in collaboration with, the solar community. Goals in FY 2009 include completion of the EIS, conducting a Final Design Review, obtaining a Special Use Permit for the Haleakalā National Park road, and applying for a building permit at the Haleakalā site through the State of Hawai'i and the conservation use district. NSO will continue shifting resources from current operations to ATST development in a manner that allows us to still provide support for the solar community with current resources, though at a reduced level.
- Continuing the detailed planning for NSO Headquarters (HQ) location and NSO consolidation. Part of this planning depends on the NSF ATST record of decision on the EIS for building on Haleakalā. As soon as that is in hand, we can negotiate with the University of Hawai'i for an ATST remote operations facility location. We will work with AURA and NSF in drafting a plan that incorporates the opportunity for an open competition amongst universities and institutions for hosting an NSO HQ facility.
- NSO has formed partnerships with Germany, Spain and Australia for a multi-station SOLIS/VSM network. Partners would host and operate the sites, after NSO develops the instruments. A proposal has been submitted to NSF/ATM with a possibility of Air Force funding.
- NSO is actively seeking external funding for the Global Oscillation Network Group (GONG) telescope operations. The Air Force plans to pay for the addition of Hα to the GONG sites and is considering providing partial funding of GONG operations. SDO launch is currently scheduled for January 2010. Thus it is our goal to have the majority of GONG funding from non-NSF/AST sources by the end of 2010. This would permit GONG to continue operations through a Hale cycle as desired by the solar community. Should external funding fail to materialize, we will begin the shutdown of GONG after one-year of cross calibration with SDO. If NASA maintains the current SDO launch date, this shutdown would begin in mid 2011.

3 FY 2009 Spending Plan

Because of uncertainty in the FY 2009 budget, we have developed three funding scenarios. In scenario one, NSO is level funded at the FY 2008 rate for the first six months, then catches up to the President's 2009 budget as presented in our cooperative agreement proposal. In scenario two, NSO remains at the FY 2008 rate for the entirety of FY 2009. In scenario three, NSO is funded at 95% of the FY 2008 budget. Another uncertainty in the budgeting is the level of funding that ATST will receive. Because certain actions are needed in the near future to meet a possible late FY 2009 early FY 2010 construction schedule, there will be a significant impact on NSO operations and projects unless ATST receives a substantial increase above the FY 2008 funding level as outlined in Section II-1.1.9.

Table V-1 summarizes the funding NSO would expect in FY 2009 at the full amount proposed in the cooperative agreement, at a flat funding based on the FY 2007 amount, and at a 5% reduction. The NSO program outlined in this program plan was developed based on receiving \$11,632K for its combined base

program (\$9,132K, Tables V-3 through V-9) and the ATST project (\$2.500K, Table V-10). As discussed in Section II-1.1.9, additional funding above \$2.5M is needed for ATST to complete what it needs to do for the EIS, permitting and Final Design. NSO receives additional operational support from the Air Force Research Laboratory (AFRL), under an MOU between the AF and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NSO earns revenue from operation of the cafeteria, the Visitor Center, and housing on Sacramento Peak. If funded at the Cooperative Agreement Proposal level, NSO would continue to invest in ramping up science and technical support for in-house efforts supporting ATST technologies (AO, cameras, IR). At the flat funding level, NSO proposes to freeze hiring, forgo a raise in 2009, reduce some operation expenses by cutting back on GONG servicing missions, travel, library purchases, and ETS support. We will also need to commit indirect earnings and some of our project multi-year funds. All of these have a negative impact on the program as well as staff morale. An alternative is a major reduction in force, which does not make sense at a time when we want to ramp up for ATST support. If, however, the FY 2010 budget appears to be flat, a reduction in force will be necessary. Another alternative would be to close one or more facilities.

Table V-1. NSO FY 2009 Funding							
(Dollars in Thousand	s)						
Scenario	CA*	Flat	Flat –5%				
NSF/AST Funding – NSO Base	9,132	8,171	7,762				
NSF/AST Funding - ATST	2,500	1,800	1710				
AFRL Support for Sac Peak Operations	400	400	400				
NSF REU/RET Program	124	124	124				
Revenue (Housing, Kitchen, Visitor Center)	171	171	171				
ATST Fellowship Support from AURA	50	50	50				
Programmed Indirects/Project Carryforward	48	303	802				
Total NSO Funding	\$12,425	\$11,019	\$11,019				

*Cooperative Agreement

Even at the Cooperative Agreement level funding, ATST has a serious issue. Funds where needed immediately to start a special use permitting process for the road to Haleakalā which passes through the Haleakalā National Park. ATST also needs to fund the completion of the EIS and contractual efforts to prepare for the final design review in March of 2009. Some of these efforts have been funded using almost all of the NSO FY 2008 indirect cost (IDC) earnings, which normally is used as the Director's reserve. We have asked NSF for supplemental funding to cover these expenses so that the NSO IDC earnings can be used in the flat-funding scenario. If we do not receive the supplemental funding that would enable NSO to replace these IDC earnings, we will need to use multi-year project carryforward or take some other action to stay within the budget.

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 then normally made available to the user community. Currently, there are several programs that fall into this category. Funding from 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 Andrew 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-1 is allocated to the various tasks NSO must perform to fulfill its mission (telescope operations, instrumentation, etc.) and categorized 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 tables showing the funding cross-referenced by functional area and task for the three levels of funding. Spending in the 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. The table shows both the full program in the cooperative agreement and reductions that would occur in the case of flat funding as mentioned above. At a 5% reduction below flat funding, the spending would be the same, but we would have to commit more of the indirects and/or project carryforward.

Table V-2. NSO FY 2009 Planned Spending by Functional Area						
(Dollars in Thousands)						
	CA* Level	Flat				
Director's Office ¹	447	442				
AURA Corporate Fee	373	330				
Educational & Public Outreach (EPO) ³	326	326				
Tucson/Kitt Peak ^{1,2}	1,855	1,729				
Sacramento Peak ^{1,2}	2,571	2,426				
GONG ¹	2,959	2,813				
ATST D&D Effort	2,452	1,766				
ATST In-House Contribution ⁴	950	817				
SOLIS	492	370				
Total NSO Program	\$12,425	\$11,019				

*Cooperative Agreement

¹Contains programmed indirects and project carryforward.

² Some payroll and non-payroll associated with ATST support and SOLIS support has been moved into the ATST in-house contribution line and SOLIS line respectively.

³Combines the EPO funding at Sac Peak & Tucson, and EPO support received from NOAO.

⁴This 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. The ATST In-house Contribution line item represents funds for the efforts of NSO Sunspot and Tucson scientific, technical and administrative staff who devote time in support of ATST but are not paid out of the ATST D&D budget. Similarly, payroll and non-payroll funds in Tucson that support SOLIS are shown in the SOLIS line in Table V-2.



Figure V-2. Distribution of FY 2009 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 towards operation of the Director's office. Non-payroll expenses include travel, supplies and materials, and other miscellaneous expenses. Committees include the semi-annual meetings of the Users' Committee and support for other committee meetings as needed to support management of the observatory.

Table V-3. Director's Office						
(Dollars in Thousands)						
Cooperative Agreement Level Flat Funding						
	Payroll	Non-Payroll	Totai	Payroll	Non-Payroll	Total
Staff	366	23	389	361	23	384
Committees	0	12	12	0	12	12
NOAO Support	32	14	46	32	14	46
Total Director's Office	\$398	\$49	\$447	\$393	\$49	\$442
Outreach Support from NOAO	78	33	111	78	33	111

Table V-4 shows the budget breakdown for Tucson operations with SOLIS broken out separately in Table V-5, eventhough it is embedded in Tucson operations. 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 Telescope.

Table V-4. NSO/Tucson								
(Dollars in Thousands)								
	(Cooperative Ag	reement		Flat Funding			
	Payroll	Non-Payroll	Totai	Payroll	Non-Payroll	Total		
Scientific Staff	426	39	465	393	39	431		
Scientific Support/Computing	209	10	219	206	10	216		
Instrument Development	443	45	488	436	45	481		
NOAO ETS	80	0	80	0	0	0		
Telescope Operations	155	77	231	152	77	229		
NOAO Support	298	74	372	298	74	372		
Total NSO/Tucson	\$1,610	\$245	\$1,855	\$1,484	\$245	\$1,729		
Outreach (REU/RET)	50	12	62	50	12	62		

Table V-5. NSO/SOLIS						
(Dollars in Thousands)						
	Cooperative Agreement				Flat Funding	
	Payroll	Non-Payroll	Total	Payroli	Non-Payroll	Total
Scientific Staff	165	50	215	45	50	95
Telescope Operations	149	128	277	147	128	275
Total SOLIS	\$314	\$178	\$492	\$192	\$178	\$370

Because SOLIS will have two vacant positions, the project would take a significant hit by a hiring freeze. We are looking into ways to mitigate this and will consider alternate ways of funding the program.

Table V-6 breaks out the Sacramento Peak operations budget. Instrument development is concentrating on MCAO and upgrades to the DST control system and focal-plane instrumentation so users can take full advantage of diffraction-limited imaging. The DST is also serving as a test bed for ATST by exploring ways to operate several instruments simultaneously. We would also like to use the DST for prototyping various ATST control software and operational concepts. 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.

Table V-6. NSO/Sacramento Peak						
(Dollars in Thousands)						
	C	ooperative Agre	eement	F	lat Funding	
· · · · · · · · · · · · · · · · · · ·	Payroll	Non-Payroll	Total	Payroll	Non-Payroll	Total
Scientific Staff	329	43	372	294	43	337
Scientific Support/Computing	138	90	228	135	90	225
Instrument Development	521	92	613	425	92	517
Telescope Operations	206	26	232	203	26	229
Facilities	267	403	670	263	403	666
Administrative Services	255	24	279	251	24	275
NOAO Support	141	35	176	141	35	176
Total NSO/Sacramento Peak	\$1,857	\$714	\$2,571	\$1,712	\$714	\$2,426
Outreach (REU/RET)	108	46	154	108	46	154

For Sac Peak, the largest impact of the hiring freeze is on the technical staff because of an open electronics engineer position. Filling this position to support DST operations and projects is crucial and we are looking at alternative ways to handle the shortfall. Table V-6 contains the \$400K contribution from the USAF as well as the revenue earned from housing, meal services, and Visitor Center sales. The USAF funding is added to NSO's general operations funding to offset the support provided 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.

Table V-7. Air Force FY 2009 Funding						
(Dollars in Thousands)						
Payroll Non-Payroll Total						
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			
Total Air Force \$242 \$158 \$						

Table V-8 summarizes the GONG spending plan for FY 2009. 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 (\$340K). These funds are not shown in the table.

Table V-8. NSO/GONG							
(Dollars in Thousands)							
	C	ooperative Agr	reement	F	lat Funding		
	Payroll	Non-Payroll	Totai	Payroll	Non-Payroll	Total	
Scientific Staff	850	30	880	816	20	836	
DMAC Operations	554	127	681	545	120	665	
Telescope Operations	503	427	930	496	360	855	
Administrative Services	183	10	193	180	2	182	
NOAO Support	220	55	274	220	55	274	
Total GONG	\$2,309	\$649	\$2,959	\$2,256	\$557	\$2,813	

3.1 ATST Program Funding

NSO personnel at both NSO sites contribute to the development of the ATST in addition to personnel directly funded by the ATST D&D proposal. In-house efforts contributing to ATST include programs to continue the development of the next generation of adaptive optics and infrared technologies, the project scientist, and scientific support. Table V-9 summarizes the NSO in-house investment in the ATST. In the flat-funding scenario, we would forgo some of the panned increase in scientific and technical support that is aimed at ramping up towards construction and operations.

Table V-9. NSO In-House Contributions to ATST						
(Dollars in Thousands)						
Cooperative Agreement Level				Flat Funding		
-	Payroll	Non-Payroll	Totai	Payroll	Non-Payroll	Total
Science Support	273	25	298	269	25	294
Technical Support	370	107	477	370	103	473
ATST Fellowship	150	25	175	50	0	50
Total In-House Contributions	\$793	\$157	\$950	\$689	\$128	\$817

Current guidance from NSF indicates that the project should plan for a late FY 2009 or early FY 2010 start of construction. If ATST is funded at the FY 2007 level of \$1.8M, there will be a serious shortfall in the ATST program which also impacts operations of current facilities. Table V-10 summarizes the funding outline in Section II-1.1.9 needed for a smooth transition into construction by fall of 2009.

Tak	ole V-10. ATS	Г	
(Do	llars in Thousands)	
	Payroll	Non-Payroll	Total
ATST Project Staff	1751	248	1,999
EIS/SUP,CDUA		660	660
Educational Outreach	86	5	91
FDR Preparation		197	197
NOAO Shared Services		205	205
AURA Fee @ 3.09%		48	48
Total for Basic Program Needs	\$1,837	\$1,363	\$3,200
Request for Construction			
Preparation/Risk-Reduction Work		\$3,110	\$3,110

If the program is funded at the FY 2007 level of \$1,800K, the minimum shortfall is \$1,400K with respect to what is needed for the basic program. Thus we are requesting a minimum supplement from NSF of \$1,400K to support the project team, complete the EIS, apply for special use permits on Haleakalā, and prepare for the Final Design Review. An additional \$3,110K is needed to conduct the various risk reduction packages that have been suggested by the PDR, cost review, and various systems level review committees.

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. NSO has invested a substantial fraction of its indirect earnings into the ATST program. 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:

- Ensure uninterrupted support to the solar community through operation of its flagship facilities until ATST replaces them.
- 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 develop a 3-station SOLIS network with international partners.
- 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 level 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

To maintain the project team, support the on-going Environmental Impact Statement (EIS) process, the Special Use Permit (SUP) development with the National Park Service (NPS), the upcoming Conservation District Use Application (CDUA) permitting process, prepare for the NSF-conducted Final Design Review (FDR), and perform recommended risk-mitigation studies with industry, NSO is requesting additional funding to the projected ATST FY 2009 budget.

A minimum of \$1.4M in addition to the \$1.8M in the Continuing Resolution is needed. In this minimum request NSO needs an additional \$543K for FY 2009 to support the payroll and non-payroll requirements of the project team. An additional \$660K is needed to support the on-going EIS process, the CDUA process, and the Special Use Permit (SUP) development with the NPS. NSO also needs \$197K to support preparations for the

NSF-conducted FDR (i.e., cost updates, Project Management Control System (PMCS) development, etc.) scheduled for March 2009.

In addition to the minimum request, NSO is also requesting an additional \$3.111M to fund Preliminary Design Review (PDR) and Systems Design Review (SDR) committee recommended risk- reduction work, prototyping and design feasibility, and cost analyses. The completion with industry of the site architectural and engineering (A&E) work and the foundation design is the highest priority item within this additional risk-reduction and vendor-contracting package. The A&E work and foundation design drives the start of work on site and therefore drives the construction critical path. Other recommended work includes adaptive optics deformable mirror prototyping (\$400K) and wavefront sensor camera development (\$400K), and further software and controls development (e.g., Common Services). These risk-reduction efforts with industry flow directly from recommendations made by design and cost-review committees.

Specific areas where funding enhancements are needed to sustain the final stages of the ATST D&D effort and to provide for a smooth transition into construction are shown in Table V-11.

Table V-11. ATST Request for Additional Funds above Flat \$1,800K				
(Dollars in Thousands)				
Amount needed to maintain project team at current level	290			
EIS/SUP/CDUA Processes	660			
FDR Preparations	197			
NOAO Shared Support/AURA Fee	253			
Minimum Request	\$1,400			
A&E Work Package & Foundation Design [\$300K];				
Construction Preparation/Risk Reduction [\$2,810]	\$3,110			
Total Requested Delta for ATST	\$4,510			

This level of funding will greatly reduce project risk, shorten the schedule, and ensure a smooth transition into construction.

3.3.2 NSO Operations and User Support

If NSO continues to be funded at the FY 2007 level throughout FY 2009, our first priority would be to recover as much of the \$960K difference between the cooperative agreement proposal base budget request (\$9,132K, excluding ATST) and the FY 2007 base budget (\$8,171K). This would allow NSO to recover frozen positions and use the project carryforward for completion of the projects for which it is intended. An additional enhancement of \$583.7K, or any fraction thereof, is requested for the specific items in Table V-12. Given the FY 2008 and current budgetary constraints, this request is the same as that made in the FY 2008 program plan. 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-12. Summary of Funding Enhancement Request							
	(Dollars in Thousands)							
Priority	Project	Est. Cost	Project Type					
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	DSTWeather Station	2	Replacement					
	Total Request	\$583.7						

Table V-12 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.

Appendix E describes each of the above items in detail.

APPENDIX A: MILESTONES FY 2009

This section describes the major project milestones for 2009.

A1. Advanced Technology Solar Telescope

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

- 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.
- Hold NSF conducted final design review, currently scheduled for early March 2009.

A2. Solar Adaptive Optics

- Continue MCAO development at the DST
- Refine 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 FY 2009 include:

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

A4. SOLIS

- Continue to observe daily and supply research-grade data to the community. This includes the acquisition of full-disk 630.2 photospheric and 854.2 chromospheric VSM magnetograms, and subsequent generation of the Carrington rotation maps, as well as the calibrated spectral data and derived line parameters as observed by the ISS.
- Confirm the scientific accuracy of VSM vector data inversions. Include inversion code into automated processing of daily data. Provide vector data online to solar community.
- Install new cameras.
- Initiate SOLIS fast-scan observations of regions likely to flare and archive new polarimetric data products from fast-scans.
- Assemble, test and install an extinction monitor to provide atmospheric line-of-sight conditions for the ISS instrument.
- Complete development of guider for VSM and FDP instruments.

A4. SOLIS (cont.)

- Integrate FDP onto the mount at the SOLIS tower.
- Upgrade machines: Centos, Java and CORBA upgrades.
- Isolate changes in the vector photospheric field parameters before and after flare events as observed in the fastscan observations.
- Integrate VSM vector photospheric and STEREO data to calculate and compare energy budgets for coronal fields and CME's.

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.
- Continue development of space weather predictive tools using ring diagrams, the far-side signal, and the highcadence magnetograms.
- Complete porting of GONG production software to Linux.
- Secure increased bandwidth from the sites sufficient to transfer full-resolution images to Tucson in near-realtime and complete the data handling system design.
- Begin development of US Air Force Weather Agency Hα observing system for deployment in FY 2010.

A6. Virtual Solar Observatory

- Continue spatial search development.
- Set up SDO data access.
- Improve catalog searches.
- Implement usage reporting system.
- Develop interfaces for C and Matlab.

A7. NSO Array Camera (NAC)

- Conduct sunspot observations with NAC 1000–2200 nm polarimeter.
- Generalize sub-array readout on NAC.
- Implement in-line software fix for single-read frame image corruption.
- Identify and purchase 3-5 micron polarization optics.

A8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

Significant progress on SPINOR development was achieved in FY 2008. Engineering runs on the DST were conducted and science data were obtained in September.

- Demonstrate Level-1 functionality by reliably taking maps, flats, darks, instrument polarization calibrations, and telescope polarization calibrations.
- Demonstrate Level-2 functionality by implementing external command and control of the DST camera control system.
- Conduct NSO staff observations.
- Develop data reduction process.
- Release SPINOR as a user instrument.

A9. Facility IR Spectropolarimeter (FIRS)

This joint effort with University of Hawai'i is currently in the final implementation phase at the DST. The milestones for FY 2009 include:

- Implement storage area network (SAN) access and integrate FIRS into DST mechanisms via the common services server.
- Conduct science runs.
- Develop operator's manual.
- Provide operator training.
- 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 fault-prone CAMAC system. Good progress on this effort was made in FY 2008 and the primary milestones for FY 2009 include:

- Complete new motion control for DST mechanisms.
- Complete A2D/D2D development.

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

The ROSA commissioning run at the DST was successfully completed in August 2008. Additional observing runs are expected to continue in the first quarter of 2009.

- Conduct engineering and science runs.
- Provide operator training.
- Release instrument to the community.

A12. McMath-Pierce Telescope Control System (TCS) Upgrade

- Install a new CCD camera for daytime and nighttime use at the telescope to replace older LN2 nighttime dewars, using a new stand-alone PC.
- Implement a 2D translating limb-guider system.
 - Specify and design.
 - 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.

A13. Planetary Adaptive Optics System for the McMath-Pierce Telescope

- Integrate with stellar spectrograph.
- Test the final cross-correlation code (developed by C. Keller).

A14. Integrated Field Unit (IFU) for the McMath-Pierce

- Develop alignment procedure.
- Test and characterize performance.
- Release instrument to users.

A15. Establish NSO Headquarters

- Release a request for letters of interest in the fall of 2009 if ATST construction is underway.
- Obtain AURA and NSF agreement on the process for selecting a headquarters site.
- Estimate costs of a headquarters for various potential locations.

APPENDIX B: STATUS OF FY 2008 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2008 Program Plan. (FY 2008 milestones appear in italics below.)

B1. ATST

- Hold final Systems Design reviews and Contract Package reviews in advance of construction.
 Project-conducted final Systems Design Reviews and Contract Package Reviews are scheduled for 04-06 November 2008.
- 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 nearing completion for the major sub-assemblies.

B2. Solar Adaptive Optics

- Resume MCAO development at the DST In progress with collaboration between NSO and the Kiepenheuer Institut f
 ür Sonnenphysik. Two observing runs were completed in FY 2008.
- Find optimum positions for the MCAO deformable mirrors. In progress.
- Develop and implement stable and efficient MCAO control algorithms. In progress.

B3. Diffraction-Limited Spectro-Polarimeter (DLSP)

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

This project was again put on hold due to limited labor resources and higher priorities.

B4. SOLIS

• Prepare a plan to handle polarization modulator degradation.

The scientific requirements for the VSM call for three different types of polarimetry modulation at two different wavelengths, 630.2 nm and 854.2 nm. To achieve these requirements, three separate modulator packages were fabricated using ferroelectric liquid crystals (FeLC) purchased from Displaytech. Unfortunately, the large (50 mm diameter) modulators within the VSM appear to degrade in quality with

variations in polarization modulation across the field of view. The ability to reliably monitor the degradation of the modulators has been compromised by the fact that the VSM calibration wave plate and polarizer rotation mechanisms had been experiencing positional repeatability problems for quite some time. The magnitudes of the positional errors have been measurable in degrees. As per the electronics and mechanical designs, they should have a repeatability of 0.01 degrees. In November 2007 a wiring error to the motors was found and corrected. Subsequent analysis of the modulator efficiency has shown that the degradation has not changed in over 8 months. In addition recent work to remove polarization fringes in the 6302V data has determined that the fringes are from the ¹/₄ wave plates and not from the FeLCs themselves. This problem can be resolved in the future by purchasing higher quality wave plates. There are field effects that appear from striations near the central field of view but these and other features due to camera electronics and scattered light are now corrected for with the revised data reduction routines.

The last replacement of the VSM modulators on Kitt Peak required approximately two weeks although the instrument was down for a longer period of time to incorporate additional design changes. For a network application we propose to modify existing access panels and mounting points to allow same-day replacement if modulator stability remains a concern. An alternative, long-term solution could be replacing existing FeLCs with a unit similar to that used in HINODE. The recent success of HINODE Solar Optical Telescope has demonstrated that an achromatic, large aperture, bicrystalline, athermal wave plate used as a rotating modulator can be fabricated that could meet the stringent scientific requirements of the VSM. This approach would require a precision motor operating at 2250 rpm and some mechanical modifications to the focal plane package. Vendors are currently available for both the optics and high-precision motor. However, nonrecurring engineering costs for a custom motor would have to be covered by other projects such as the Advanced Technology Solar Telescope (ATST) that require large, rapidly rotating wave plates.

• Install new cameras.

Three cameras (one spare) have been purchased and delivered from Sarnoff with modifications to better meet the VSM scientific requirements. Data output of the new cameras is 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 been completed and testing has been performed in the lab and at the observing site. Data has been taken in the lab to develop routines for removing fringes caused by the cameras. Modifications to data analysis software have been completed to the point were actual observations are now needed to progress further. Installation of the cameras will proceed as weather permits during the first quarter of FY 2009.

• Upgrade machines to Centos, Java upgrade and CORBA upgrade.

The code within SOLIS has been modified to make it POA-compatible and usable with the upgraded version of Java. The code is now ready to be installed into the main SOLIS release when the Linux machines are upgraded. In addition the connection to VxWorks using a new version of OmniORB name service has been tested, also in anticipation of machine upgrades. The SAN was replaced with a RAID system, providing for greater storage capacity and better performance. Resources were spent on implementing a test bed for pipeline testing. This test bed has been extremely helpful because it permits frequently-needed testing and code modification to be made in an environment insulated from science code development and the summit pipeline. This has accelerated the updating of pipeline code on the summit so that it now reflects as closely as possible the code that is up to date in the CVS repository. Stokes full-disk two-pass processing infrastructure is in place and stokes pipeline processing is nearing completion, awaiting new science code. A study has been completed that outlines in detail the hardware and software upgrade path for SOLIS data processing. The study includes estimates of resources and risks associated with various approaches. Hardware will be purchased in stages to maximize processing power and insure long term serviceability.

B4. SOLIS (cont.)

• 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 iodine cell for determining absolute spectralline shift and an extinction monitor to account for sky transmission. A commercial company was commissioned to fabricate an iodine cell with orthogonally mounted wedged windows that met the requirement of no fringing. The mechanical mounting was modified to accommodate the new cell design and aligned to the existing fiber network. This calibration unit has now been operational since April of 2008. The spectral sensitivity characteristics of the new Sony "FLEA" camera have unfortunately limited the filter selection for the extinction monitor. Specifically the green image has proven to be the most difficult to accommodate. Polarizing materials with adhesive backing have been purchased and will be used to construct tunable trim filers to adjust the wavelength intensities. Lab testing is on-going with the goal of having the unit ready for operational testing in the first quarter of 2009. Additional effort will be required in software to analyze the extinction monitor images and apply corrections to the spectral data. Full implementation of a calibration routine will 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. Completion of this final instrument for the SOLIS three-instrument suite has been the last to be scheduled since similar observations are available from other sources. All major hardware has been purchased and the operating software has been completed. The system has been aligned up to the final beam splitter and has had the mechanism motors tuned for reliable operation. A print circuit board for controlling the H α tunable filter FeLCs has been designed and fabricated. Preliminary data will be taken during the first quarter of FY 2009 prior to completion of the limb guider. Calibration and data processing algorithms are required for FDP observations before the instrument is deployed. 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 2008, with lab qualification tests to take place in the first half of FY09.

• Complete development of guider for VSM and FDP instruments.

There have been various design attempts to implement the array readout electronics, with varying degrees of success and failures. The latest design has discarded the analog multiplexing scheme and replaced it with four, dual channel ADC ICs which were not commercially available until recently. An upgraded version of the signal processing board was obtained from the original board manufacturer for testing purposes but unfortunately the science requirements could not be realized. Requirements were then modified to better match commercially available hardware. The current design is to use the new detector head with the original DSP board but modify the method that the solar limbs are detected. This new design will use the FPGA to calculate consecutive pixel differences and store the position and value of the absolute difference maximum and minimum. The FPGA will also keep a running sum of each odd/even pixel on each array to be used in bright sky/cloud detection and array gain correction. By allowing the FPGA to do the array readout and derivative calculations a total of 40 measurements (5*4 arrays *2 (odd and even pixels)) should be accomplished with existing FPGA resources. Freeing the DSP from participating in the array readout will provide ample processing time for the 2 centroid calculations as well as all the other processing the DSP is required to do. Approximately 2 man months have been estimated for completion of the position encoder development and another 2 man months for Components Controller driver development and integration into the FDP instrument (Fall 2008) in preparation for integration into the VSM.

B4. SOLIS (cont.)

• Continue to improve raw data reduction and calibration methods for the VSM.

Extensive resources have been allocated over the past year to remove fringes in the 6302V data. The fringes are due to polarization modulation variability during successive scan lines and flat-field observation. Recently two full disk magnetograms have been processed with good results. The process developed has three components: Some preprocessing on a polarization flat, stage 1, and stage 2. The preprocessing creates S/I spectra from the flat (where S is Q,U,V). These are used to produce maps of how the fringe phase departs from a simple quadratic fit to position along the slit and also the fringe amplitude verses slit position. In stage 1 the raw spectra are converted to I, Q/I, U/I and V/I one scan line at a time. Leakage of intensity into the various modulator state spectra is reduced by using fixed biases and gains applied to each camera quadrant and modulation state. The calibration slit and camera flats are used to normalize the spectra. Streaks along wavelength are removed by a thresholded mean determination and subtraction. A model of the fringes is then fit to each camera and each S state. The fit results are subtracted from the S/I values and there is a second round of streak removal both along rows and columns. Stage 2 reduces the remaining artifacts by looking at the entire scan lines in order. At each pixel and each S/I it determines and subtracts a bias value as a function of scan line number. This is done by an adaptive running mean calculation that uses thresholds to avoid strongly polarized areas. With the proper parameters this removes the slowly changing artifacts from the spectra rather effectively. At the moment, there is a tendency for opposite polarity artifacts to be introduced after the running mean filter passes over certain strong polarization features. This can be reduced by varying the two adjustable parameters in the filter or by keeping the updating off for a few points after the filter passes over a strong feature. The final output of stage 2 is I,Q,U,V.

• Initiate SOLIS fast-scan observations of regions likely to flare.

This has not started because Solar Cycle 24 has not begun.

- *Calibrate and archive new polarimetric data products from fast-scans.* This has not started because Solar Cycle 24 has not begun.
- Identify magnetic footpoints associated with polar plumes.

This has been accomplished. See the following by Nour-Eddine: Raouafi, N.-E., Petrie, G. J. D., Norton, A. A., Henney, C. J., Solanki, S. K., 2008, "Evidence for Polar Jets as Precursors of Polar Plume Formation", Astrophysical Journal, 682, 137. Raouafi, N. E., Petrie, G. J. D., Norton, A. A., Henney, C. J., 2008, "Evidence for polar jets as early stage of polar plume formation", AGU Fall Meeting, SH31A-09.

• Integrate VSM vector photospheric and STEREO data to calculate and compare energy budgets for coronal fields and CME's.

This has not been accomplished due to SOLIS not providing Gordon Petrie with an adequate set of vector data. The delay was due to the difficulty in developing and implementing code to remove the polarization fringes. Note: the NASA grant only began Jan 2008 so we have until January 2009 to accomplish our year 1 goals associated with that grant. This was one of the goals.

• Draft a plan for building a SOLIS network through partnerships.

In January 2008, NSO submitted a pre-proposal to the NSF/Atmospheric Sciences Division Mid-Size Infrastructure (ATM/MSI) Opportunity program to build two near-duplicates of the VSM to be stationed 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) supplied letters of interest in which they offered support for operational costs. There were several good referee comments that helped fine tune the text for submission at a later date. In addition there were some misunderstandings that required clarification and were addressed with improved text. The NSO was subsequently invited to submit a full proposal that was then submitted on the 2nd of June 2008. In addition a paper and poster were prepared for the June 23 - 28 SPIE conference on Ground-based and Airborne Instrumentation for Astronomy II.

B5. GONG

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

A new interface to the GONG data archive has been developed and installed. The time-distance pipeline is still on hold, pending further refinements to the magnetogram processing pipeline.

• Continue to develop magnetic field products as requested by the solar physics and space weather communities.

The near-real-time capability now produces continual ten-minute average full-disk magnetograms, hourly synoptic maps, eight different projections of the extrapolated coronal magnetic field, spherical harmonic coefficients, and magnetic field changes.

• Develop space weather predictive tools using ring diagrams, the far-side signal, and the high-cadence magnetograms.

Subsurface vorticity derived from ring diagrams has been demonstrated to be highly correlated with flare production. A statistical forecast of near-side activity derived from the far-side maps is under development. Progress has been made on implementing the production of merged one-per-minute magnetograms.

• Continue porting GONG's production software to Linux.

The porting project is nearly complete, with only one major pipeline module remaining.

• 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, and will be further improved with the H α data. A continual bandwidth monitoring process has been installed. 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 continue to be made to the design of the search results pages

- Add more archives.
 Added O-SPAN data set.
- Add additional catalogs.
 Added NOAA x-ray and active regions catalog

B7. NSO Array Camera (NAC)

• Streamline NAC 1000–2200 nm polarimeter control.

In January 2008 the NSO hired a new scientific programmer to develop a more robust operating system for the NAC. This task of streamlining polarimeter control was completed and has met qualification testing.

- *Develop looping capability in the NAC script language.* This capability has been realized and is in normal operation.
- Develop real-time flat and dark correction for the NAC.

Flat and dark correction are now done in real time and incorporated into normal observations.

Purchase 50 × 50 mm square 4666 nm filter for CO lines.
 This and several other filters were purchased in March of 2008.

B8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- Complete SPINOR.experiment control (SEC)
 Level-1 functionality was completed.
- Complete virtual camera and camera control computer development. Completed.
- Conduct engineering run to connect SPINOR control software to DST interfaces. Completed.
- Conduct engineering runs to workout details of SPINOR operation. Completed.
- Complete data processing package. In progress.
- *Conduct science observing run with staff scientist.* Completed. Data is currently being evaluated.
- Release instrument to user community.

Good progress continues towards this milestone. The instrument is in debug mode and additional development is necessary to make operations more stable and user friendly.

B9. IR Polarimeter

- Finalize the optical bench layout for 0.6302 and 1.56 microns. Completed.
- *Complete the mechanical work.* Completed.
- Implement SAN access and integrate FIRS into DST mechanisms via the common services server. In progress.

B9. IR Polarimeter (cont.)

- Conduct science runs.
 Completed.
- *Release to the user community.* Good progress was made towards this milestone.

B10. Dunn Solar Telescope Critical Hardware (System Upgrade)

- *Implement new A2D/D2A* Mostly completed.
- Implement new motion control via VME.

Mostly completed. Hardware is in-hand and software has been developed. These two activities were put on hold during the year in order to accommodate ATST high-order adaptive optics wave-front sensor digital signal processor prototyping.

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

- Provide electrical, mechanical, and optical interface support. Completed.
- Provide support for shipping & customs. Completed.

B12. DST Data Storage Upgrade

- Define project requirements and scope. Completed.
- Identify processes to be developed. Completed.
- Develop and implement processes. Completed.
- Test and release.
 Project completed.

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

- Replace existing Dec PDP-11.73 telescope control computer with a modern PC running a PDP emulator.
- An emulator and its associated I/O hardware have been purchased and undergone preliminary testing. The system has been configured to emulate existing components and successfully tested using Livingstone's long-range observing program. The Kitt Peak Multitasking Forth operating system was loaded onto the emulator and used to control the pointing of the telescope. The system is now in a final testing phase to ensure reliability.
- Implement a 2D translating limb-guider system.

This task has been subdivided into discrete components and staged for completion in FY2009. The Infrared Adaptive Optics (IRAO) bench has been reconfigured and is now able to be moved below the

spectrograph rotating table to accommodate the limb-guider platform. In addition new hardware has been purchased to better interface the spectrograph rotation encoder to computer control. A preliminary guider design will be presented for review during the first quarter of FY2009.

B14. Planetary Adaptive Optics System for the McMath-Pierce Telescope

- *Finalize the wave front sensor optical design.* This task has been completed.
- Conduct initial testing.
 - Initial testing has been completed and the system is operating using software in beta release.
- Mount the system on the McMP stellar spectrograph.
 - This task has been completed.
- Conduct final testing and first science observations.

The system has been critically tested and was scheduled for scientific observations in the 4^{th} quarter of FY 2008.

B15. Integrated Field Unit (IFU) for the McMath-Pierce Telescope

• Mount IFU on the spectrograph ahead of the input slit.

In August 2008 D. Ren (California State U.-Northridge) returned to the McMP with a modified design of the image slicer. Unfortunately there was too much cross talk between the mirror segments when adjusting the alignment. After consultation it was decided that the design should be modified one more time and work was scheduled with the mirror fabricator. IFU mechanical drawings are now in house and will be used to design and construct a support platform for the instrument. The re-designed instrument will be delivered in December 2008 and undergo qualification testing. The IFU is expected to be a user instrument early in 2009.

APPENDIX C: NSO FY 2009 BUDGET & STAFFING SUMMARY

NSO FY 2009 Budget Summary (Cooperative Agreement Proposal Level)

Director's						Total
Office	Sunspot	Tucson	GONG	ATST	SOLIS	Budget
401				-		401
	372	465	880	473	215	2,405
	228	219	681			1,127
	613	568	279	477		1,937
	232	231	651		277	1,392
	670					670
	279		193			472
111	154	62				326
46	176	372	274	205		1,074
				2,248		2,248
325				48		373
al 883	2,724	1,917	2,959	3,450	492	12,425
(24)	(0)	(0)	(24)			(48)
	(104)					(104)
	(17)					(17)
	(62)	(62)				(124)
	(400)					(400)
				(50)		(50)
	(50)					(50)
s 859	2,091	1,855	2,935	3,400	492	11,632
	Director's Office 401 111 46 325 883 (24) (24) s 859	Director's Office Sunspot 401 372 228 613 232 670 279 111 232 670 279 111 154 46 176 325 (24) (0) (104) (177) (62) (400) (24) (0) (104) (177) (62) (400) (50) (50) s 859 2,091	Director's Office Sunspot Tucson 401 372 465 228 219 613 568 232 231 670 279 111 154 62 46 46 176 372 325	Director's Office Sunspot Tucson GONG 401 372 465 880 228 219 681 613 568 279 232 231 651 670 79 193 111 154 62 25 74 325 0 883 2,724 1,917 2,959 (24) (0) (0) (24) (104) (17) (62) (62) (62) (400) 5 5 859 2,091 1,855 2,935	Director's Office Sunspot Tucson GONG ATST 401 -	Director's Office Sunspot Tucson GONG ATST SOLIS 401 -

(Dollars in Thousands)

NSO FY 2009 Budget Summary (Flat Funding) (Dollars in Thousands)

	,						
-	Director's	0	T	0010	A.T.O.T.	00110	Total Budget
Expenses	Unice	Sunspot	Tucson	GONG	AISI	50LIS	Buuget
Director's Office	396				-		396
Scientific Staff		337	431	836	344	95	2,043
Scientific Support/Computing		225	216	665			1,106
Instrument Development/Maintenance		517	481	257	473		1,728
Telescope Operations		229	229	599		275	1,332
Facilities		666					666
Administrative Support		275		182			457
Educational & Public Outreach	111	154	62				326
NOAO Business Support	46	176	372	274	148		1,017
ATST					1,618		1,618
AURA Management Fee	296				34		331
Program Total	849	2,579	1,791	2,813	2,617	370	11,019
Revenues							
Programmed Indirects/Carryforward	(61)	(149)	(69)	(24)			(303)
Housing Revenue	• •	(104)	. ,	. ,			(104)
Meal Revenue		(17)					(17)
NSF REU/RET Funding		(62)	(62)				(124)
Air Force Support		(400)	. ,				(400)
ATST Fellowship Support		()			(50)		(5 <i>0</i>)
Visitor Center Revenue		(50)			()		(50)
NSF/AST Funds	788	1,797	1,660	2,789	2,567	370	9,971

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

FY 2009 Staffing Schedule

APPENDIX D: SCIENTIFIC STAFF RESEARCH AND SERVICE

(*Grant-supported staff)

Olga Burtseva, Research Associate

<u>Areas of Interest</u>

Local Helioseismology, Solar Activity

<u>Recent Research Results</u>

Burtseva studied influence of surface activity on the latitudinal distribution of travel times of acoustic waves in the upper solar convection zone using GONG data. 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 reduces the travel-time difference between solar maximum and minimum only in active latitudes, but does not eliminate the latitudinal dependence of the travel times completely. At non-active latitudes, the travel times are about 0.5 sec shorter at solar maximum in comparison with those at solar minimum that might be evidence of global changes in latitudinal distribution of sound speed over the solar cycle.

Burtseva studied the influence of the active region that emerged on the solar surface in October 2003 on travel time measurements using MDI data. 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 and also a statistical study is necessary.

Burtseva studied lifetimes of high-degree solar p-modes in the quiet and active Sun at both maximum and minimum of the solar cycle. The lifetimes were computed from SOHO/MDI data in four different phases of solar activity in an area including active regions and a quiet Sun area using the time-distance technique. The results from the area with active regions show that the lifetime decreases as activity increases. The lifetime computed in the quiet region still decreases with solar activity although the decrease is smaller. Thus, measured lifetime increases when regions of high magnetic activity are avoided. The increase in the lifetime in the quiet area relative to the area with active regions is proportional to the difference between the magnetic field strength of the quiet area and the area including active regions. Moreover, the lifetime computed in quiet regions also shows variations with activity cycle. Paper to Solar Physics is under preparation.

Burtseva analyzed amplitudes of high-degree solar p-modes in the quiet and active Sun at both maximum and minimum of the solar cycle. Two different methods, the ring-diagram technique and the peak profile fitting of the power spectrum were applied to GONG and MDI data to analyze p1 - p4 ridges as a function of the mode degree. Active regions of certain magnetic field strength were masked out and the masked and unmasked acoustic power was compared. The results show that the amplitude at the solar maximum decreases after mask is applied up to the mode degree -300 - 400 and then increases for higher degree modes, while at the solar minimum the amplitude after masking decreases along all the mode degrees range. In order to comprehend the changes in amplitude, a numerical simulation with circular artificial masks of different radius was performed. From the results it appears that the variation in the amplitude seen above could be due to the effect of the mask or center-to-limb variations of the velocity.

Future Research Plans

Burtseva plans to extend the analysis of the amplitudes of high-degree solar p-modes in the quiet and active Sun at minimum and maximum of the solar cycle. This study is an attempt to understand if the mode parameters of the Quiet Sun vary with solar cycle and does the Quiet Sun have more acoustic power at solar minimum in comparison with solar maximum or vice versa. This work can help to make advances in detecting of emerging active regions before they appear on the solar surface which is an important goal of space weather.

*Michael Dulick, Scientist

<u>Areas of Interest</u>

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

<u>Research</u>

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

<u>Service</u>

Dulick serves as the NSO FTS Instrument Scientist for visiting investigators funded by an NSF Chemistry grant for Laboratory Fourier Transform Spectroscopy and a grant from the NASA Upper Atmospheric Research Program (UARP), with specific duties that include providing assistance in the experimental design and setup and the instructional use of the instrument.

David F. Elmore, Instrument Scientist

<u>Areas of Interest</u>

Development of ground-based spectrograph and filter-based polarimeters including both current instruments at NSO and new instruments for the Advanced Technology Solar Telescope (ATST). Collaboration with NSO staff and visiting scientists to explore new spectro-polarimetric capabilities—spectral regions, processing techniques, and measurement calibration.

Recent Research Results

As project manager, Elmore oversaw the successful test flight of the SUNRISE stratospheric balloon payload. In 2009 SUNIRSE will lift, above 98% of Earth's atmosphere, a 1-m diameter solar telescope that will record the highest resolution solar images to date. Elmore designed the spectrograph and polarization optics used for spectro-polarimetry aboard the Japanese Hinode satellite. Hinode, now completing its second year of operation in space, is providing breakthrough solar observations.

Future Research Plans

Work with prospective instrument developers to define and develop instrumentation for the ATST. Thoroughly understand telescope calibration at the Dunn Solar Telescope and apply that knowledge to develop the telescope calibration plan for ATST. Utilize existing instruments at NSO, SPINOR, ProMag, and IBIS, to advance spectro-polarimetric techniques.

<u>Service</u>

Elmore is Instrument Scientist for the ATST. In that role he works with instrument builders and ATST team members to define the instruments and their interfaces. As Instrument Scientist for the SPINOR instrument at the DST, Elmore works with staff and visitors to assure that instrument meets the needs of the community.

Mark S. Giampapa, Astronomer

<u>Areas of Interest</u>

Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

Recent Research Results

Giampapa and his collaborators published their results of a 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 following up the M67 study with an observational program that will focus on other activity diagnostics and projected rotation measures. Time was awarded on the ESO VLT with collaborator Ansgar Reiners (University of Göttingen) to obtain high resolution spectra for v sin I measurements of selected M67 sun-like stars. Giampapa is a Co-Investigator in a joint University of Arizona/NOAO-NASA Astrobiology 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, are investigating 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 is being pursued. Giampapa plans to use the SOLIS ISS for long-term studies of the Sun-as-a-star.

<u>Service</u>

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 is the PI for SOLIS as well as the instrument scientist for the SOLIS Integrated Sunlight Spectrometer (ISS). 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; Giampapa is the chair of the Kitt Peak Telescope Allocation Committee (TAC) 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 and has been a long-time member of the NAS/NRC Associateships Review Panel. Like other NSO scientific staff members, Giampapa participates in educational outreach activities, including K-12, undergraduate, graduate, and general public educational programs and activities. He was recently appointed the Diversity Advocate for the NSO. Giampapa is an adjunct astronomer at the University of Arizona.

*Irene González Hernández, Assistant Scientist

<u>Areas of Interest</u>

Local Helioseismology (Seismic Imaging and Ring-Diagram Analysis)

<u>Recent Research Results</u>

González Hernández is currently leading 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 magneticactivity in such measurements.

<u>Future Research Plans</u>

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 front side. 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.

<u>Service</u>

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 <u>http://gong.nso.edu/emerging/</u>.

John W. Harvey, Astronomer

<u>Areas of Interest</u>

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

<u>Recent Research Results</u>

During FY 2008, J. Harvey worked on SOLIS and GONG instrument development and maintenance, on a NASAfunded 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. Work continued with J. Sudol (West Chester University of Pennsylvania) on a systematic study of magnetic field changes associated with flares observed with GONG. An investigation of transient features visible in Hinode XRT images with respect to the structure and dynamics of the underlying magnetic field was continued. A comparison of simultaneous SOLIS and Hinode magnetograms led to a surprising conclusion that there is less small scale radial magnetic flux in the photosphere than anticipated based on model predictions. Relatively low resolution observations capture most of the flux seen in high resolution observations. In preparation for installation of new cameras in the SOLIS VSM, Harvey developed a new method for removing fringes caused by CCD etalon effects in monochromatic light. He applied the knowledge gained in this effort to the task of eliminating fringes in VSM vector polarization data.

<u>Future Research Plans</u>

During FY 2009, J. Harvey will continue to concentrate on development of SOLIS and GONG. In particular, installation of new cameras and investigation of a more robust modulator for the SOLIS/VSM, completion of the SOLIS/FDP and design and implementation of an H α observing capability for GONG.

He intends to critically review and homogenize codes for synoptic map production 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. He hopes to complete a comparison of Hinode XRT data with high cadence full-disk magnetograms. He continues to work with a group at SAIC that is attempting to put solar magnetic field measurement on a sound quantitative basis.

<u>Service</u>

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

Frank Hill, Senior Scientist

<u>Areas of Interest</u>

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

<u>Recent Research Results</u>

Hill continues to perform research in helioseismology. Recent work with R. Komm and others has focused on the relationship of subsurface vorticity and surface magnetic flux to the flare productivity of an active region. We find that, when both vorticity and flux are high, the active region has very high probability of producing flares. The temporal variation of the subsurface vorticity seems to be a leading indicator of flaring, and may lead to a space weather predictive tool.

Working with Irene González Hernández, and Shukur Kholikov, Hill has been investigating high-precision measurements of the solar acoustic radius, which is related to the depth dependence of the acoustic cutoff frequency. We have found that it is possible to continually measure the acoustic radius with either the autocorrelation function of low-degree p-mode time series or the disk-average far-side phase shift. In both cases, the estimated radius is highly anti-correlated with the surface activity. This is due to thermal changes immediately below the photosphere caused by the presence of magnetic fields. The low-degree autocorrelation method should work quite well for asteroseismology studies of stellar interiors.

<u>Future Research Plans</u>

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. He is also working on detecting subsurface magnetic fields with ring diagrams; looking for flare-related changes in the oscillations; developing a power-spectral method to study prominence dynamics; and studying the oscillations of the longitudinal magnetic field.

<u>Service</u>

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. Hill typically supervises several staff, currently seven scientists, one manager, and one programmer. He participated in the NOAO TLRBSE program, producing a software package to reduce and analyze McMath-Pierce NIM and NAC IR data.

Rachel Howe, Associate Scientist

<u>Areas of Interest</u>

Helioseismology, the Solar Activity Cycle, Peak Fitting

<u>Recent Research Results</u>

Work on the solar rotation, on solar-cycle changes over 12 years of medium-degree observations, and on local frequency variations from ring-diagram analysis, is ongoing and in preparation. Howe has recently submitted an invited review article on "Solar Interior Rotation and its Variation" for *Living Reviews on Solar Physics*, and gave an invited talk at the recent international GONG/SOHO meeting on "Magnetic Fields and Temporal Variation. 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 meetings held in Napa, CA in March 2008 and Stanford, CA in February 2007.

<u>Future Research Plans</u>

Howe intends to continue working on the above areas.

<u>Service</u>

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 2008 AGU/SPD and GONG/SOHO meetings. She assisted with the organization of the 2007 NSO Summer Workshop, with particular responsibility for preparing the abstract booklet and editing the proceedings volume, published in 2008 as ASP Conference Series Volume 383, *Subsurface and Atmospheric Influences on Solar Activity*.

*Kiran Jain, Assistant Scientist

<u>Areas of Interest</u>

Helioseismology, Solar Cycle Variation, Ring-Diagram Analysis, Sub-Surface Flows, Properties of the Solar Atmosphere, Solar Activity, Irradiance Reconstruction, Empirical Modeling, Sun-Earth Connection.

<u>Recent Research Results</u>

Using simultaneous observations in photosphere and chromosphere, Jain studied characteristics of highdegree modes such as frequency, amplitude, line width and their variation with the type of spectral line used to observe solar oscillations. The analysis has shown that there is a significant variation in mode amplitude for different spectral lines; however, mode frequencies and line width or life-time of the modes do not vary with the choice of spectral line. It is also found that there is a difference in power suppression in the regions of strong magnetic field with increasing height. Jain also examined the subsurface flows calculated by inverting frequencies which are found to remain unchanged with the selection of spectral line.

Jain analyzed intermediate degree *p*-mode eigen frequencies measured by GONG and MDI/SOHO over a solar cycle to study the source of their variability. The correlation analysis between the frequencies shifts and several measures of the Sun's magnetic activity sensitive to changes at different levels in the solar atmosphere suggests that the degree of correlation differs from phase to phase of the cycle. During the rising and the declining phases, the mode frequencies are strongly correlated with the activity proxies, whereas during the high-activity period, the frequencies have significantly lower correlation with most of the proxies. It clearly shows that both components of the magnetic field are important in modifying the oscillation frequencies and more than 95% of the variation can be explained by changes in both components during all phases of the activity cycle.

<u>Future Research Plans</u>

Jain will continue to investigate the effect of the choice of spectral line and observable on helioseismic mode parameters and subsurface flows using simultaneous data sets. In addition, Jain plans to compute regression models for solar total and spectral irradiances on different timescales. This will enable us to study the effect of solar eruptive events on short-term irradiance variability and model parameters. Efforts will be made to identify key solar activity indices that can serve as surrogates to solar irradiance in the absence of observations and to construct a composite time-series using existing records of Ca II K emission index to study long-term variations in irradiance and global cilmate in the last century. Jain (with González Henández) will also correlate Lyman-alpha irradiance with near-side total LOS magentic flux and forecast its value 7- to 21 days in advance from far-side helioseismic signal.

<u>Service</u>

Jain is the coordinator of NSF funded International Research Experience for Students (IRES) program for NSO.

Shukirjon S. Kholikov, Assistant Scientist

<u>Areas of Interest</u>

Helioseismology, Data Analysis Techniques, Time-Distance Methods

<u>Recent Research Results</u>

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 are published in *Solar Physics*.

<u>Future Research Plans</u>

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 measurement of flow in high latitudes. He will continue working on meridional flow

measurements using zonal spherical harmonics coefficients (m=0, m=1, m=2). He is also working on ridge fitting problem for high L part of solar p-mode spectra which will be first attempt of obtaining frequency tables of acoustic modes for L=200-1000 degrees using GONG data.

Stephen L. Keil, NSO Director

<u>Areas of Interest</u>

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, Phil Judge, and Scott McIntosh of the High Altitude Observatory (HAO), Tom Schad, a 2006 NSO REU student from the University of Notre Dame, 2006 NSO RET teacher Daniel Seeley from Farmington High School in Massachusetts, Dan Tran, a 2007 NSO REU student from Boston University, and Alexandre Bibeau-Delisle, a 2007 Summer Research Associate, 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. He worked with the ATST team on several publication updating the ATST design and status. Keil conducted DST observations of pre-filament eruption surface flows and velocities in conjunction with SOHO Joint Observing Program 178 and analyzed the data understand the relationships between shearing motions and the eruption of the filament.

Future Research Plans

Keil is leading efforts to develop the Advanced Technology 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 and obtain better measurements of the coronal field. As part of this effort an agreement was established between NSO, HAO and the University of Hawaii to relocate the Coronal One Shot to Haleakala where we expect to encounter more consistent coronal sky conditions..

<u>Service</u>

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

*Rudolf W. Komm. Associate Scientist

<u>Areas of Interest</u>

Helioseismology, Dynamics of the Solar Convection Zone, Solar Activity and Variability

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. Komm is 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. Komm has begun exploring the relationship between the twist of subsurface flows and the flare production of active regions. For this purpose, he is collaborating with K.D. Leka and G. Barnes (CoRA, NWRA) to apply statistical tests based on discriminant analysis (DA) to several subsurface flow parameters with the goal to differentiate between flaring and non-flaring 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 the daily variations of subsurface flows of active regions.

<u>Service</u>

Komm continues as coordinator of the Local Helioseismolgy Comparison Group (LoHCo). He supervises both graduate and undergraduate students, conducting research programs during the summer.

John W. Leibacher, Astronomer

<u>Areas of Interest</u>

Helioseismology, Atmospheric Dynamics, Asteroseismology

<u>Recent Research Results</u>

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 eigen-frequencies on which helioseismology is based, new techniques for measuring solar subsurface meridional circulation and its variation with the solar cycle, as well as the variation of the helioseismic signal with altitude in the solar atmosphere and the intercomparison of measurements from different instruments and different techniques.

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, with potential applications to the upcoming SDO/HMI and Picard/SODISM observations. The application of helioseismic techniques to stellar oscillations is being pursued in the framework of the CoRoT mission and the upcoming Kepler mission and the Antarctic Dome-C instrument SIAMOIS. The limits to exoplanet detection using radial velocity measurements are being explored with colleagues at the IAS (Orsay) and the Observatoire de Genève.

<u>Service</u>

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 organizes the weekly NSO-LPL (University of Arizona Lunar and Planetary Laboratory) seminar series. He has been a mentor to an undergraduate physics student for three of the last six summers and two graduate students all using GONG data, has been the external examiner on two PhD theses and a member of four PhD juries. 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 member of the Fachbeirat (scientific advisory committee) of the Max Planck Society's Institute for Solar System Research (Katlenburg-Lindau), chaired the site visit of the NSF Science and Technology Center for Integrated Space Weather Modeling (CISM), and was a member of the visiting committee of the Yale University Department of Astronomy and the external review Naval Research Laboratory's Space Research and Technology program. He is editor of the journal *Solar Physics*.

Aimee A. Norton, Assistant Astronomer

<u>Areas of Interest</u>

Spectro-polarimetry, Solar Atmospheric Energy Transport, MHD Waves, Observational Aspects of Solar Dynamo, Instrument Development

Recent Research Results

Norton, Petrie & Raouafi (ApJ, 2008, 682, 1306) 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. 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.

<u>Future Research Plans</u>

Norton has recently observed the quiet Sun with the Spectro-polarimetric for Infrared and Optical Regions (SPINOR) instrument at the Richard B. Dunn Solar Telescope. Five separate maps were observed simultaneously in the visible and the infrared wavelength regime. These maps were acquired during a deep Solar minimum time period and should provide excellent statistics on the small-scale fields present in the photosphere.

<u>Service</u>

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

<u>Areas of Interest</u>

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 19932003, 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.

<u>Future Research Plans</u>

Penn is currently involved in vector magnetic field observations using the 1565 nm infrared lines and spectroscopy using lines at 4000-4700nm from the McMath-Pierce telescope.

<u>Service</u>

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. Other recent work on the NAC includes

improving the NAC scripting language, streamlining the polarization control system and refining the camera single-frame read operations mode. 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) and Research Experiences for Teachers (RET) programs 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.

*Gordon J. D. Petrie, Assistant Scientist

<u>Areas of Interest</u>

Solar Magnetic Fields

Recent Research Results

G. Petrie has ten years of experience in theoretical solar physics. He came to Tucson in 2005 as a visiting scientist in residence on a NASA/GSFC postdoctoral appointment associated with NASA's STEREO mission, and in 2007 he joined NSO as an assistant scientist. Petrie helped to develop and test the new GONG magnetogram pipeline using KPVT and SOLIS VSM data processing tools, coronal magnetic field models and comparisons with SOLIS VSM data products. He is currently working on projects exploiting the STEREO/SECCHI data and the GONG magnetogram products. GONG is the official provider of magnetograms for NASA's STEREO mission.

<u>Service</u>

During the summers of 2006 and 2007, G. Petrie mentored an NSO RET teacher on solar wind forecasting tools for high school students using SOLIS VSM synoptic coronal hole maps. He also mentored an NSO REU student in summer 2008.

Alexei A. Pevtsov, Associate Astronomer

<u>Areas of Interest</u>

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

<u>Recent Research Results</u>

Pevtsov worked with researchers from NSO and other institutions on helicity of solar magnetic fields, role of topology of solar magnetic fields in prominence eruptions, and study of solar activity using historic data sets (spectroheliograms in Ca II K spectral line).

Helicity measurements from Marshall Space Flight Center vector magnetograph, Haleakalā Stokes Polarimeter, Okayama Observatory Solar Telescope, and Mitaka Solar Flare Telescope all show periods when the hemispheric helicity rule reverses its sign. However, these periods of sign-reversal do not agree well between different instruments. Furthermore, statistical analysis of data suggests that due to nature of the hemispheric helicity rule (weak tendency with significant scatter), the sign-reversals are statistically unreliable. Such reversals can be explained by a random data sample of a noisy "parent population" of data set.

<u>Future Research Plans</u>

A. Pevtsov plans to continue his studies of magnetic and current helicities on the Sus. He will continue analyzing historic records of Ca II K observations, and participate in research on prominences and Moreton waves.

<u>Service</u>

Pevtsov serves as the Solar Physics Discipline Scientist at NASA Headquarters, the Program Scientist for Solar and Heliospheric (SH) Supporting Research and Technology (SR&T) Program, and the Program Scientist for five NASA solar missions: Hinode, RHESSI, SOHO, SDO, TRACE. He reviewed proposals for several NASA programs and served as a reviewer for three professional publications, *Astrophysical Journal, Solar Physics, and Publications of the Astronomical Society of Japan.* He is co-convener of special session on "Topological Space Weather Forecasting" at 2008 Fall AGU meeting in San Francisco. A. Pevtsov teaches two on-line undergraduate classes at New Mexico State University.

Thomas R. Rimmele, Astronomer

<u>Areas of Interest</u>

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

<u>Recent Research Results</u>

During the past two years, Rimmele has co-authored several papers in refereed astronomical journals. Rimmele studied magneto-convective processes in sunspots and compared observational results in the context of competing models for sunspot fine-structure (Rimmele 2008, ApJ, 672, 684). In collaboration with the IBIS group from Arcetri, Rimmele published a paper (A&A) that presents an overview of the quiet solar chromo-sphere as observed in the Ca II 854.2 nm line at high spatial, spectral, and temporal resolution. These IBIS observations are the first observations of this type and quality for any chromospheric calcium line. Rimmele leads the NSO and ATST solar adaptive optics (AO) and Multi Conjugate AO programs. In collaboration with graduate students from Kiepenheuer Institute, Freiburg and post-docs at NSO and University of Florida, he implemented a new MCAO bench setup at the Dunn Solar Telescope and demonstrated the ability to correct an extended field of view (compared to conventional AO). This work was presented and published at the recent Air Force Maui Optical and Superconducting Site (AMOS)-08. In collaboration with his post-doc F. Wöger, Rimmele published a study of the effect of anisoplanatism on the measurement accuracy of an extended-source Hartmann-Shack wavefront sensor (ApOpt, 48, 35) simulating the high-order ATST AO system. Other ATST activities were published in a number of recent SPIE and COSPAR proceedings. Rimmele spent two months at National Astronomical Observatory of Japan (NAOJ) in Tokyo as Hinode Guest Investigator. He gave several talks and lectures at NAOJ and University of Kyoto and presented the ATST project at the European Solar Physics Meeting (ESPM08) in Freiburg.

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 and continuously decreasing amount of time available for research.

<u>Service</u>

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. Rimmele participated in EAST council meetings as ATST representative with the goal of identifying potential collaborative efforts between ATST and the European Solar Telescope (EST). 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 supervises recent PhD recipient Jose Marino (NJIT), who is now at the University of Florida, 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. Hawai'i IfA) 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. Rimmele serves as a member of the AO Planning Committee for the 2009 Optics and Photonics Congress, collocated with Frontiers in Optics/Laser Science (FiO/LS) XXV to be held October 11-16, 2009 in San Jose, California. He continues to serve as referee of a number of papers submitted to astrophysical and technical journals.

*William H. Sherry. Research Associate

<u>Areas of Interest</u>

Formation and Evolution of Low-Mass Stars; Evolution of Magnetic Activity of Low-Mass Stars; Extra Solar Planets.

<u>Recent Research Results</u>

W. Sherry uses main sequence fitting to determine the distance to the Ori cluster. The Ori cluster is an important cluster because it is a young, 3 Myr old, cluster with a significant population of brown dwarfs. Results for this project were published in Sherry et al., 2008.

Sherry has analysed photometric observations of solar type stars in the Pleiades and found that the average level of variability is greater for ~100-Myr-old Pleiades stars than for random field stars with similar apparent brightnesses. Mark Giampapa presented these results at the Cool Stars XV meeting in summer 2008, and Giampapa and Sherry are preparing a paper describing these observations.

Future Research Plans

W. Sherry plans to continue the photometric monitoring of solar type members of the Pleiades with Mark Giampapa. They plan to extend their work using a new instrument that should allow them to sample the light curves with much higher cadence (10 times per hour versus once per day) and greater precision. In 2009, W. Sherry will work on observations of M67. At an age of 4 Gyr, M67 is the oldest cluster in their study of the evolution of magnetic activity in solar type stars over the lifetime of the Sun.

W. Sherry plans to continue his observations of young low-mass stars in Orion OB1. His Orion project has been awarded six half nights on the KPNO 4-m telescope with the MOSAIC camera to extend his optical survey of two of the assiation's groups. He has applied for time in the spring 2009 semester for near infrared observations on the KPNO 4-m telescope with NOAO's NEWFIRM instrument.

W. Sherry is also working with NOAO's Steve Howell to use speckle interferometry to identify binary stars in the field of view of the KEPLER space telescope, which is due to launch in 2009.

<u>Service</u>

W. Sherry worked closely with Mark Giampapa's 2005 NSO REU student Christopher Beaumont, and he supervised 2008 KPNO REU student Matthew Henderson. Sherry continues to work with Matt Henderson for his senior thesis project at Clemson University.

W. Sherry serves as referee or one or two journal papers per year. He has participated in several NSO and KPNO public outreach events, including serving as judge at a local science fair and participating in a "star party" for a local elementary school.

Clifford G. Toner, Associate Scientst

<u>Areas of Interest</u>

Global and Local Helioseismology, Data Processing and Analysis Techniques

<u>Recent Research Results</u>

Toner is working on 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 pars in $10^{**}6$ to -1 part in $10^{**}5$.)

<u>Service</u>

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.

*Roberta M. Toussaint, Assistant Scientist

<u>Areas of Interest</u>

Development and implementation of numerical algorithms to monitor, calibrate and reduce image data as well as testing and certification of solar instruments.

<u>Recent Research Results</u>

Toussaint developed and implemented an improved method for flat-fielding SOLIS integrated sunlight spectrometer (ISS) spectra data, tested and certified ISS as producing science-quality data, helped with the development of algorithms for reduction of Ca K and Ca H parameters and time series. Most recently, she has been working on calibration issues with the SOLIS vector spectromagnetograph (VSM), specifically removing influences of strong magnetic fields from the vector flats and removing modulation fringes from the Stokes polarizations. The fringe removal is accomplished by fitting the observed fringes to a two-dimensional fringe model and then removing the fringes analytically. (The model was suggested by C. Keller). Although this leaves some residual fringes, these are removed by a temporal detrending method developed by J. Harvey.

<u>Future Research Plans</u>

Toussaint plans on continuing to improve raw data reduction and calibration methods for the VSM which includes updating and maintaining calibration procedures. She will work on initiating SOLIS fast-scan observations of regions likely to flare. This will include calibration and archiving new polarimetric data products from the fast-scans, ensuring that the new area scan archive is useful to outside users. Work on the characterization of canopy fields is also planned.

<u>Service</u>

Toussaint has been involved with public outreach programs through NSO and NOAO. This includes participation as a science fair judge at the local and regional levels and classroom visits to local elementary, middle, and high schools. She has been an astronomer partner in Project ASTRO and a participant in the Family ASTRO programs as well as a co-mentor (with W. Livingston) to an REU student who was working on a comparison of ISS CaK results with results from the McMath Pierce telescope.

*Sushanta C. Tripathy, Assistant Scientist

<u>Areas of Interest</u>

Global Helioseismology: Frequencies and Mode Parameters from Time Series of Short and Long-Periods, Local-helioseismology: Local analysis of Quiet, Active and CME Source Locations, Comparison of Spectra from Different Observables, Activity Cycle.

Recent Research Results

S. Tripathy for the first time established that the solar oscillation frequencies can be reliably measured with sufficient precision on time scales as short as nine days. Using ten years of GONG data, he showed that the frequency shifts derived from nine days are significantly correlated with the strength of solar activity and are

consistent with log-duration measurements from GONG and SOHO/MDI instrument. The study also indicated that the magnetic indices behave differently in the rising and falling phases of the activity cycle. For the short duration nine-day observations, he reports a higher sensitivity to activity.

S. Tripathy has analyzed the frequencies and asymmetry of high degree modes derived from both velocity and intensity data observed by MDI. Fitting the three dimensional spectra with asymmetric profiles, he observed systematic frequency differences between the two spectra at high-end of the frequency range, mostly above 4 mHz. He inferred that this difference arises from the fitting of the intensity rather than the velocity spectra. He also showed that the frequency differences between intensity and velocity do not vary significantly from the disk center to the limb and concluded that only a part of the background is correlated with the intensity oscillations.

<u>Future Research Plans</u>

S. Tripathy will continue to devote his time analyzing and comparing MDI and GONG data both globally and locally. Specifically, it is planned to study the effect of the magnetic field on the oscillation frequencies in order to comprehend the source of the frequency shifts. He will also continue to search for activity precursors in the flow fields using data from MDI, GONG and SOLIS.

<u>Service</u>

S. Tripathy supervised an NSO REU student during summer 2006.

Alexandra Tritschler, Research Associate

<u>Areas of Interest</u>

High-spatial resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere, fine structure of sunspots in particular the penumbra, image reconstruction, simulations of the influence of atmospheric turbulence and instrumentation on solar observations, post-focus instrumentation.

<u>Recent Research Results</u>

The most recent research result is accepted as a Letter contribution to the *Astrophysical Journal*. A. Tritschler and colleagues present observational evidence for the existence of a current sheet in the chromosphere above a sunspot umbra based on high angular resolution two-dimensional spectroscopic observations in the Ca II 854.21 nm line. In the core of this line, a very stable, bright ribbon-like structure separating magnetic field configurations that connect to different parts of the active region was observed. It is plausible that the structure is a string of sheets carrying vertical currents that result from dissipation when the different parts of the active region are moved around in the photosphere. To Tritschler's and colleagues' knowledge, this is the first direct observation of the heating caused by the dissipation in such a current sheet in the chromosphere.

<u>Future Research Plans</u>

Tritschler's main science interests have been focused on the high-resolution (spectral and spatial) aspects of solar physics and the fine structure of sunspots and pores in particular. She intends to pursue this interest further and employ the capabilities of IBIS (and in the future FIRS or SPINOR) to observe the photospheric and chromospheric layers of active regions.

<u>Service</u>

Tritschler has been mentoring summer REU and SRA students, and she is a member of the Sac Peak telescope allocation committee (TAC). She has served on proposal panel reviews and has been a reviewer of publications for the *Astrophysical Journal, Astronomy and Astrophysics*, and *Solar Physics*.

Han Uitenbroek, Associate Astronomer

<u>Areas of Interest</u> Radiative Transfer Modeling, and Structure and Dynamics of the Solar Atmosphere

<u>Recent Research Results</u>

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 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 invsetigated 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

<u>Future Research Plans</u>

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 fro 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.

deduce the formation height of spectral lines relative to that of the continuum.

<u>Service</u>

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 Marshall Space Flight Center. Uitenbroek is serving on the PhD thesis committees of Catherine Grec, University of Nice, France, and Sarah Jaeggli at the University of Hawaii.

Friedrich Wöger, Assistant Scientist

<u>Areas of Interest</u>

Image Reconstruction, Adaptive Optics, Two-Dimensional Spectroscopy, and Spectropolarimetry

<u>Recent Research Results</u>

Wöger worked with Oskar von der Lühe (Kiepenheuer-Institut für Sonnenphysik, Germany) and Kevin Reardon (Osservatorio Astrofisico di Arcetri, Italy) on photometrically reliable speckle image reconstruction algorithms. Using data observed with the high order adaptive optics system (HOAO) installed at the Dunn Solar Telescope (DST) in combination with data observed with the HINODE satellite they found that near real time speckle image reconstruction can be performed to a high photometric accuracy if the adaptive optics system's performance is well characterized. This is achieved by new models for the transfer function of Earth's turbulent atmosphere and the adaptive optics system. Recently, Wöger has worked with Thomas Rimmele on the simulation of the effect of atmospheric anisoplanatism on the measurement accuracy of a Hartmann-Shack wave front sensor, in an effort to study requirements for the Advanced Telescope Solar Telescope.

<u>Future Research Plans</u>

Wöger is involved in research of the solar dynamic magnetic chromosphere in collaboration with Sven Wedemeyer-Böhm (Institute for Theoretical Astrophysics). He will pursue to observe this region in the solar atmosphere using spectro-polarimetric measurements with the IBIS instrument installed at the DST to analyze acoustic and magneto-acoustic features. The major diagnostic will be the Ca II infrared line at 854.2 nm, but also the H-line at 656.3 nm will be included in his analysis in the future.

<u>Service</u>

Wöger is in charge of the data handling at the DST, and is supervising the movement of the standard data product from tapes to hard drives.

APPENDIX E: FACILITIES AND MAINTENANCE PLAN (FY 2009)

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 39) broken down by site. Given the FY 2008 and current budgetary constraints, this request is the same as that made in the FY 2008 program plan.

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 Hawai'i 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 2008 carryforward 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. NATIONAL SOLAR OBSERVATORY





AASC	Astronomy and Astrophysics Survey Committee
AAS	American Astronomical Society
AFRL	Air Force Research Laboratory
AFWA	Air Force Weather Agency
AIS	Advanced Image Slicer
AMOS	Advanced Maui Optical and Space Surveillance (Technologies)
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)
CORBA	Common Object Requesting Broker Architecture
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	Eidgenössische Technische Hochschule- Zürich
EUV	Extreme Ultraviolet
F&A	Facilities & Administration (AURA Fee)
FASR	Frequency Agile Solar Radiotelescope
FBR	Final Baseline Review
FDP	Full-Disk Patrol (SOLIS)
FDR	Final Design Review
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 (NASA)
GUI	Graphical User Interface
HAO	High Altitude Observatory
HMI	Helioseismic and Magnetic Imager (SDO Instrument)
HSG	Horizontal Spectrograph
HT	Hilltop Telescope
IAC	Instituto de Astrofisica de Canarias (Tenerife, Spain)
IBIS	Interferometric BI-dimensional Spectrometer
ICC	Instrument Computer Control
ICD	Interface Control Document
IDC	Indirect Cost
IFA	Institute for Astronomy (University of Hawai'i)
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)
IT&C	Integration, Testing, and Commissioning (ATST)
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 Helioseismolgy 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
MOU	Memorandum of Understanding
MREFC	Major Research Equipment Facilities Construction
MRI	Major Research Instrumentation (NSF)
NAC	NSO Array Camera
NAOI	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
NIIT	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
NPS	National Park Service
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
NST	New Solar Telescope (NJIT/BBSO)
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 Adavanced Technology Attachment
SCB	Sequential Chromospheric Brightening
SCSI	Small Computer System Interface
SCOPE	Southwest Consortium of Observatories for Public Education
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
SPU	Special Use Permit
SRA	Summer Research Assistant
SRD	Science Requirements Document
SSB	Space Science Board
STEREO	Solar TErrestrial RElations Observatory
SUP	Special Use Permit (ATST)
SXT	Soft X-ray Telescope (Yohkoh)
TAC	Telescope Allocation Committee
ТВ	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
VMBICAL	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
Yohkoh	"Sunbeam," Satellite project of the Japanese Institute of Space and Astronautical Sciences
ZIMPOL	Zürich IMaging POLarimeter
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