NATIONAL SOLAR OBSERVATORY FY 2009 ANNUAL PROGRESS REPORT & FY 2010 ANNUAL PROGRAM PLAN



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MISSION

The mission of the National Solar Observatory (NSO) is to provide leadership and excellence in solar physics and related space, geophysical, and astrophysical science research and education by providing access to unique and complementary research facilities as well as innovative programs in research and education and to broaden participation in science.

NSO accomplishes this mission by:

- providing leadership for the development of new ground-based facilities that support the scientific objectives of the solar and space 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, and recruiting underrepresented groups;
- 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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EXECUTIVE SUMMARY

The National Solar Observatory (NSO) is the primary provider of key ground-based solar facilities to the U.S. solar community. NSO currently provides a range of assets that allow solar astronomers to probe all aspects of the Sun, from the deep interior to its interface in the corona with the interplanetary medium. NSO provides scientific and instrumentation leadership in helioseismology, synoptic observations of solar variability, and high-resolution studies of the solar atmosphere in the visible and infrared.

Major components of the National Solar Observatory 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.
- Combining NSO synoptic programs into a single program.
- 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.

Some of the highlights of the NSO program in FY 2009 include:

- A successful ATST Final Design Review (FDR). This included a review of all aspects of management, cost, plans for construction, and design.
- Development of accurate Milne-Eddington inversions of the SOLIS data.
- Completion of the University of Hawai'i Facility Infrared Spectropolarimeter (FIRS) at the Dunn Solar Telescope (DST) and making it available to users.
- The observational discovery of current sheets above a sunspot umbra in an active region using Interferometric BIdimensional Spectrometer (IBIS) data taken at the Dunn Solar Telescope.
- Long-term GONG observations showing the solar acoustic radius (depth at which sound waves reflect) varies with the solar cycle.
- Demonstration of a link between solar subsurface vorticity and the occurrence of solar flares.
- A solar migration toward the equator of the high-speed jet associated with solar torsional oscillation as a possible cause of the delayed start of the current solar cycle.
- Observations of a decline in the field strength and darkness of sunspots.

A few of the major actions to advance solar physics that NSO will undertake in FY 2010 include:

- Beginning construction of the Advanced Technology Solar Telescope through the NSF Major Research Equipment Facilities Construction (MREFC) program. The ATST will be the premier ground-based facility for high-resolution studies of solar magnetism and dynamics in the solar atmosphere. It will support the next generation of solar researchers as a primary tool for probing the Sun.
- Transitioning technical and scientific personnel from NSO's current programs to ATST construction. Some but not all of these positions will be backfilled as needed to maintain user support and maintenance of the telescope.
- Begin the process of combining SOLIS and GONG into a single synoptic program, allowing us to take advantages of synergisms in data and technical support.

Figure 1 summarizes NSO's FY 2010 program plans. The program is strongly focused toward developing the skills and expertise needed for NSO operations in the ATST era, while maintaining NSO's high-quality user support at current facilities as the ATST is developed. Approval of projects and programs at the large NSO telescopes is based on contributions to ATST technology and operations, such as diffraction-limited imaging and spectropolarimetry, infrared technologies, and telescope and instrument controls.

ATST management has started implementing its staffing plan to carry out the construction phase of the project. Bid packages for the telescope mount assembly, enclosure, and primary mirror have been developed and will be released in late 2009 or early 2010. A construction supervisor, support facility supervisor, contract officer, software personnel, wavefront correction scientist, optical engineer, and mechanical engineer have been hired. In addition to the ATST work packages that will be put out for bid, NSO will undertake several work packages at Sacramento Peak in areas of its expertise including the polarization modulation and calibration package, the coudé room layout, cameras, the visible broadband imager (VBI), and wavefront correction. Although thermal IR is not planned as an ATST first-light capability, it will be an important follow-on capability that can be developed using the McMath-Pierce Solar Telescope (McMP).

The SOLIS vector spectromagnetograph (VSM) and the integrated spectrometer (ISS) are currently operational on Kitt Peak and are producing highly accessed synoptic data. The VSM provides unique vector magnetograms that enable new types of synoptic maps. VSM full-disk and selected active region vector magnetograms are available from the NSO Digital Library and are being used to support *Hinode*. A worldwide network of SOLIS instrumentation was one of the low-cost recommendations of the previous Decadal Survey. NSO will use the experience gained with implementing the VSM to explore partnerships for developing a network of vector magnetographs.

High-resolution data products from GONG are now being widely used for local helioseismic exploration of sub-atmospheric structure, and GONG's near-real-time farside pipeline is fully operational. GONG's rapid cadence magnetograms and farside imaging are proving to be valuable tools for understanding space weather. In light of this, NSO is actively seeking funding for GONG to address the recommendations of the Senior Review. Recently, the U.S. Air Force has provided GONG with funds to develop an H-alpha imaging capability, which should be completed this summer. We anticipate that the Air Force will provide operational funds that will allow us to fulfill the recommendations of the Astronomy Division Senior Review.

NSO's spending plan (Section 7) reflects the need to continue the strong community momentum developed for the ATST project, the resurgence of significant interest in producing high-resolution

images with existing facilities using adaptive optics and new diffraction-limited instruments, and exploitation of the new, highly valuable synoptic data sets that result from the GONG upgrade for at least a solar activity cycle, and completion of SOLIS. The plan assumes an ATST construction start in FY 2010.

NSO 2010 Program
• ATST
 Release construction contract packages
 Begin site construction
Dunn Solar Telescope (all ATST related activities)
 Continue development of multi-conjugate adaptive optics
 Testbed for ATST instrument development
 Conduct Scientific Operations
McMath-Pierce Solar Telescope (all ATST related activities)
 Dedicate Advanced Image Slicer (AIS) and Integral Field Unit (IFU)
 Enhance control system to exploit NAC (1–5 microns) and thermal-IR
 Conduct scientific operations
• GONG
 Continue streamlining operations
 Add H-alpha capability
 Establish funding partnership(s)
 Incorporate into synoptic network with SOLIS
SOLIS
○ Operations
 Incorporation into Digital Library and Virtual Solar Observatory (VSO)
 Incorporate into synoptic network with GONG
Digital Library and Virtual Solar Observatory
 Continue work on version 1.2.3; operation of NSO node
$_{\odot}$ Continue strong collaboration with U.S. and European institutions
 Start Development of Data Center to incorporate ATST & SOLIS Data
Headquarters (HQ) Development and Staff Consolidation
 Release solicitation for HQ location
 Begin Selection Process
Education and Outreach and Broadening Participation
 Training of the next generation of solar astronomers
 Increase outreach to underrepresented minorities

Figure 1. Planned and ongoing programs and projects at NSO.

1 INTRODUCTION

The Sun exhibits many phenomena that defy explanation. Research in solar physics is a critical part of the nation's natural science program and a discipline of proven fundamental importance to physics and astrophysics. The Sun is the only star whose interior, surface, and outer atmosphere can be resolved in detail, hence providing an important and unique base for the study of fundamental physics, astrophysics, fluid mechanics, plasma physics, and magnetohydrodynamics (MHD). The interplay of these aspects of physics creates an essential range of phenomena visible not only on the Sun, but also elsewhere in the universe. The physical and temporal scales observable on the Sun are large enough to properly represent cosmic-scale phenomena, while the Sun is close enough that measurements can be made in great detail. The study of the Sun as a star guides astronomers in their investigations of other stars.

Solar physics is entering a new period in which the coupling of advanced instrumentation and detailed modeling are challenging what solar physicists think they know about the Sun and the solar processes that affect life on Earth and govern interplanetary space. MHD simulations of magneto-convection and models of chromospheric and coronal magnetic fields have enjoyed considerable progress as computation capabilities increase. These models are providing detailed predictions of the evolution of surface structure and magnetic fields that are pushing and often surpassing the ability to test the models with observations having sufficient resolution in both time and space. Solar science is a mature discipline that has developed questions of fundamental importance not only to solar physics, but also to astrophysics and plasma physics. Among these questions are: Why does the Sun have a magnetic field? How does the Sun produce cycles of varying activity? What causes sunspots? How does the Sun produce violent explosions? Answers to these questions will help with understanding and someday predicting the influence of the Sun on Earth and space weather, and understanding the role of the Sun and its variability in the evolution of life in planetary systems.

NSO remains on a path to achieve the objectives in its long range plan. These include bringing ATST on line, finishing SOLIS, establishing a robust synoptic program by combining SOLIS and GONG and finding strong non-NSF support for GONG operations, and establishing a new NSO headquarters where we can consolidate our scientific staff. This Annual Progress Report and Program Plan discussion highlights the progress during execution of NSO's FY 2009 program and plans for FY 2010.

Section 2 provides a brief description of both science and development highlights achieved with NSO facilities and projects. Section 3 provides a description of scientific and key management staff. Section 4 describes NSO tools and facilities and the support they provide the solar user community. Section 5 describes our major initiatives and Section 6 presents the major aspects of our Educational and Public Outreach (EPO) plan and our plan to increase diversity at NSO and in the solar community. Finally, Section 7 lays out the FY 2010 organization and spending plan needed to carry out the NSO program. The appendices contain user and publication statistics, completed and upcoming milestones, funding tables, organizational charts and descriptions of scientific staff research.

2 FY 2009 SCIENTIFIC RESEARCH AND DEVELOPMENT HIGHLIGHTS

2.1 Evidence for a Current Sheet above a Sunspot Umbra

Alexandra Tritschler (NSO), Han Uitenbroek (NSO), and Kevin Reardon (INAF-Arcetri) have used the Dunn Solar Telescope to obtain 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 they observed a very stable bright ribbon-like structure separating magnetic field configurations that connect to different parts of the active region. These observations provide evidence of the plausibility 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 their knowledge, Tritschler and colleagues believe this is the first direct observation of heating caused by the dissipation in such a current sheet in the chromosphere. A complete discussion on this topic is published in ApJ, 686: L45-L48, 10 Oct. 2008.

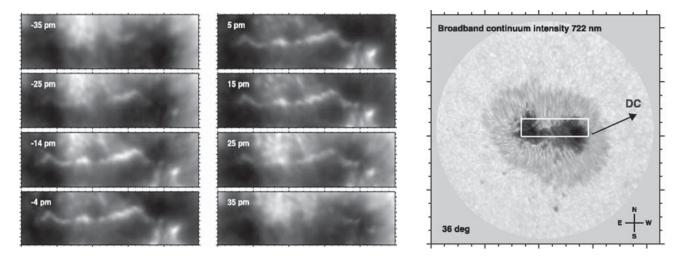


Figure 2.1. Selected wavelengths through the Ca II 854.21 nm line showing the central part of the umbra where the ribbon-like structure appears as marked by the white rectangle in the image of the broadband continuum intensity at 722 nm on the left. Indicated wavelength positions are given with respect to the line-core position of the line profiles averaged over areas outside the sunspot. Major tick marks in the x- and y-directions correspond to 5" and 1", respectively.

2.2 Are Sunspots Different during This Solar Minimum?

For hundreds of years, humans have observed that the Sun has displayed activity where the number of sunspots increases and then decreases at approximately 11-year intervals. Sunspots are dark regions on the solar disk with magnetic field strengths greater than 1500 gauss (see Figure 2.2-1), and the 11-year sunspot cycle is actually a 22-year cycle in the solar magnetic field, with sunspots showing the same hemispheric magnetic polarity on alternate 11-year cycles. The last solar maximum occurred in 2001, and the magnetically active sunspots at that time produced powerful flares causing large geomagnetic disturbances and disrupting some space-based technology. But something is unusual about the current sunspot cycle. The current solar minimum has been unusually long, and with more than 670 days without sunspots through June 2009, the number of spotless days has not been equaled since 1933 (see *http://users.telenet.be/j.janssens/Spotless//Spotless.html*). The solar wind is reported to be in a

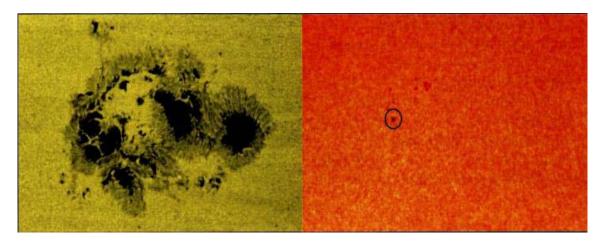


Figure 2.2-1. (left) An image of a sunspot group near the maximum of the last solar cycle, cycle 23, taken at the McMath-Pierce telescope, Kitt Peak, Ariz., on 24 October 2003. The sunspots clearly show a dark central umbra surrounded by a brighter; filamentary penumbra. The magnetic fields range from 1797 to 3422 gauss. (right) An image consisting only of pores—weak sunspots with no penumbral structure—taken from the Michaelson Doppler Imager (MDI) instrument on the Solar and Heliospheric Observatory (SOHO) spacecraft on 11 January 2009; this is an example of what is observed today at solar minimum. The lower pore (seen as the dot in the center of the black circle) had a magnetic field of 1969 gauss; the others were not measurable. Presently, the solar surface is mostly devoid of spots. Both images have the same spatial scale and are roughly 250,000 kilometers across.

uniquely low energy state since space measurements began nearly 40 years ago [Fisk and Zhao, 2009]. See *EOS, Transactions*, 90, 257-258, 28 July 2009 for a detailed discussion about this work. In previous work, Penn and Livingston (2006) showed that the magnetic field strength in sunspots was decreasing with time, independent of the sunspot cycle. A simple linear extrapolation of those data suggested that sunspots might completely vanish by 2015.

What could be happening? Clues can be found in the infrared magnetic field strength measurements obtained at the McMath-Pierce solar telescope on Kitt Peak. The measurements suggest that throughout the time period covered by the infrared data the

relationship between umbral magnetic and infrared intensity, as seen in the darkest position in individual spots, has remained constant (see Figure 2.2-2). This reveals that sunspots seen currently are not independently getting more intense in the infrared; sunspots today still follow the same infrared intensity and magnetic field strength relationship seen in previous years. Instead, magnetically weaker sunspots are seen more frequently now with correspondingly higher infrared intensities.

Whether this is an omen of long-term sunspot decline in field strength and intensity, analogous to the Maunder Minimum, remains to be seen. Other indicators of the solar activity cycle suggest that sunspots must return in earnest within the next year. Because other indications point to the Sun presently experiencing an unusual period of minimum solar activity, it is critically important to measure the Sun's magnetic activity during this unique time. The NSO

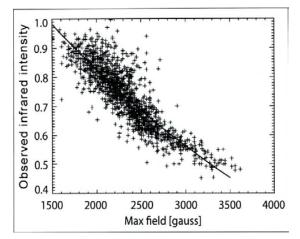


Figure 2.2-2. The observed infrared intensity in the darkest position of sunspot umbrae is plotted versus the magnetic field strength for 1392 sunspots (using the Zeeman splitting of the neutral iron spectral line at 1564.8 nm). A quadratic fit to the data is also shown. The measurements are from the entire data set observed from 1992 to 2009.

scientific staff and members of the community will continue to observe the Sun using infrared diagnostics at the McMath-Pierce telescope with keen interest.

2.3 The Solar Chromosphere at High Resolution with IBIS. II. Acoustic Shocks in the Quiet Internetwork and the Role of Magnetic Fields

The exact nature of the quiet solar chromosphere and especially its temporal variation, are still subjects of intense debate. One of the contentious issues is the possible role of the magnetic field in structuring the quieter solar regions. A. Vecchio (INAF-Arcetri and U. della Calabria), G. Cauzzi (INAF-Arcetri and NSO Visiting Scientist), and K. P. Reardon (INAF-Arcetri and NSO Adjunct Scientist) have characterized the dynamics of the quiet inter-network chromosphere by studying the occurrence of acoustic shocks and their relation with the concomitant photospheric structure and dynamics, including small scale magnetic structures. Vecchio and colleagues have analyzed a comprehensive data set that includes high-resolution chromospheric (Ca II 854.2 nm) and photospheric (Fe I 709.0 nm) spectra obtained with the IBIS imaging spectrometer at the Dunn Solar Telescope in two quiet-Sun regions. This is complemented by high-resolution sequences of MDI magnetograms of the same targets. From the chromospheric spectra the spatio-temporal occurrence of the acoustic shocks have been identified and

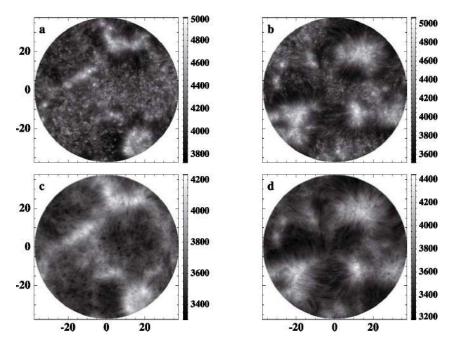


Figure 2.3-1. Maximum (top row) and minimum (bottom row) intensity of the Ca II line core throughout the 55 mn sequences. Left: data set 1; right: data set 2. The scale has been set in radiation temperature (K, see text for details). This representation of the data immediately provides a distinction among the three ma*jor chromospheric components:* the bright network, the acoustic chromosphere where acoustic shocks show up as tiny bright points, and the magnetic chromosphere threaded by slanted fibrils that can appear as either dark or bright.

compared with the photospheric dynamics by means of both Fourier and wavelet analysis and study the influence of magnetic structures on the phenomenon.

Results: Mid-chromospheric shocks occur within the general chromospheric dynamics pattern of acoustic waves propagating from the photosphere. In particular, they appear as a response to underlying powerful photospheric motions at periodicities nearing the acoustic cut-off, consistent with 1-D hydrodynamical modeling. However, their spatial distribution within the supergranular cells is highly dependent on the local magnetic topology, both at the network and internetwork scale. Vecchio, Cauzzi, and Reardon have found that large portions of the internetwork regions undergo very few shocks, since they are "shadowed" by the horizontal component of the magnetic field. The latter is betrayed by the presence of chromospheric fibrils, observed in the core of the Ca II line as slanted structures with distinct dynamical properties. The shadow mechanism also appears to operate on the very small scales of inter-network magnetic elements, and provides for a very pervasive influence of the magnetic field even in the quietest region analyzed. The

principal chromospheric components identified in the observations of Vecchio et al. are illustrated in Figure 2.3-1.

Conclusions: The magnetic field might play a larger role in structuring the quiet solar chromosphere than normally assumed. The presence of fibrils highlights a clear disconnection between the photospheric dynamics and the response of the geometrically overlaying chromosphere. As these results hold for a midchromospheric indicator such as the Ca II 854.2 line, it is expected that diagnostics formed in higher layers, such as UV lines and continua, will be affected to a greater extent by the presence of magnetic fields, even in quiet regions. This is relevant for the chromospheric models that make use of such diagnostics. Full details about this work appear in A&A, 494, 269-286, 2009.

2.4 A New Way to Infer Variations of the Seismic Solar Radius

Irene González Hernández (NSO), Phil Scherrer (Stanford U.) and Frank Hill (NSO) have published (ApJ, 691, L87-L90, 01 Feb. 2009) the discovery of a solar cycle variation in the background of daily farside maps of the Sun's magnetic activity. (Daily maps are shown on the NSO/GONG Web site (http://gong.nso.edu/-data/farside/). Gonzalez Hernandez and colleagues show that the mean phase of waves propagating all the way from the far side of the Sun to the front side, as measured by seismic holography, varies with time. The change is highly anti-correlated with solar cycle activity and is consistent with other recent results on the variation of the seismic radius of the Sun. The observed phase change corresponds to a few kilometers difference in the seismic solar radius from solar maximum to solar minimum in agreement with inferences from global helioseismology studies.

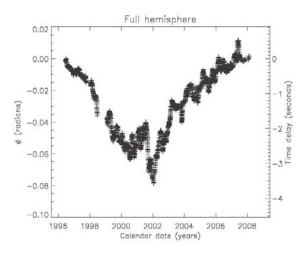


Figure 2.4 Mean phase vs time.

2.5 A Comparative Study of Magnetic Fields in the Solar Photosphere and Chromosphere at Equatorial and Polar Latitudes

Besides their own intrinsic interest, the correct interpretation of solar surface magnetic field observations is crucial to our ability to describe the global magnetic structure of the solar atmosphere. Photospheric magnetograms are often used as lower boundary conditions in models of the corona, but not data from the nearly force-free chromosphere. NSO's Synoptic Optical Long-term Investigations of the Sun VSM (Vector Spectromagnetograph) produces full-disk line-of-sight magnetic flux images deriving from both photospheric and chromospheric layers on a daily basis. Gordon Petrie (NSO) and 2008 NSO REU student Irina Patrikeeva (Northwestern U.) investigated key properties of the magnetic field in these two layers using more than five years of VSM data. They found from near-equatorial measurements that the east-west inclination angle of most photospheric fields is less than about 12°, while chromospheric fields expand in all directions to a significant degree. Using a simple stereoscopic inversion, they found evidence that photospheric polar fields are also nearly radial but that during 2008 the chromospheric field in the south pole was expanding superradially. Petrie and Patrikeeva obtained a spatially resolved polar photospheric flux distribution up to 80° latitude whose strength increases poleward approximately as cosine(colatitude) to the power 9-10. This distribution would give a polar field strength of 5-6 G. These results are published in ApJ, 699, 871-884, 2009, in which implications for future synoptic map construction and modeling are also briefly discussed.

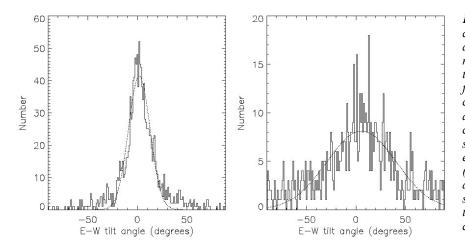


Figure 2.5. Photospheric and chromospheric magnetograms look almost identical but, according to measurements of line-of-sight fields as they pass across the disk, photospheric fields are generally nearly radial while chromospheric fields expand in all *directions to a significant degree,* consistent with canopy structure, as suggested in these histograms of the east-west tilt angles for photospheric (left) and chromospheric (right) fields along with the best fit Gaussians shown. The photospheric fields have *tilt angle* 1.8 ± 10.8 *degrees and the* chromospheric fields 5.5 ± 35 degrees.

2.6 Solar Multi-Conjugate Adaptive Optics (MCAO) at the Dunn Solar Telescope

Solar adaptive optics has become an indispensable tool at ground-based solar telescopes. Driven by the quest for ever higher spatial resolution observations of the Sun, solar adaptive optics are now operated routinely at major ground-based solar telescopes. The current high-resolution solar telescopes, such as the Dunn Solar Telescope, are in the one-meter class and utilize AO for >95 % of the observing time to achieve the diffraction limit at visible and near-IR wavelengths. Solar observations are performed over an extended field of view. The limited size of the isoplanatic patch, over which conventional adaptive optics provide diffraction-limited resolution is often a severe limitation. Post-processing is required to achieve the uniform, diffraction-limited imaging over an extended FOV. However, speckle interferometry as well as other post-facto restoration methods typically rely on short exposure imaging, which in most cases cannot be deployed when quantitative spectroscopy and polarimetry is performed, i.e., long exposures are required. In the visible, conventional AO limits the corrected FOV to about 10 arcsec or less. In contrast, a sunspot or active region extends typically over 1-2 arcmin. Flares can occur "unannounced" anywhere in the extended FOV. Flare trigger mechanisms operate rapidly and on the smallest spatial scales. Their location within the FOV is difficult, if not impossible, to predict. Thus, we are led directly to a requirement for diffraction-limited resolution over a FOV of 1-2 arcmin. Multi-conjugate adaptive optics is a technique that provides real-time diffraction-limited imaging over an extended FOV.

MCAO will eliminate a major limitation of conventional AO systems, the small isoplanatic patch, and thus provides the tool to effectively study, with unprecedented spatial resolution, fundamental scientific questions like the onset and evolution of flares, flare triggering mechanisms, magnetic reconnection events, and many other dynamic solar phenomena that require diffraction-limited observations over an extended FOV with the requisite high temporal cadence.

The development of MCAO for existing solar telescopes and, in particular, for the next generation largeaperture solar telescopes is thus a top priority at NSO. The Sun is an ideal object for the development of MCAO since solar structure provides "multiple guide stars" in any desired configuration. At the DST, we implemented a dedicated MCAO bench with the goal of developing well-characterized, operational MCAO. The MCAO system uses two deformable mirrors conjugated to the telescope entrance pupil and a layer in the upper atmosphere, respectively. The high-altitude deformable mirror can be placed at conjugates ranging from 2 km to 10 km altitude. We have successfully and stably locked the MCAO system on solar granulation, using up to five guide regions in the field-of-view. We demonstrated the MCAO system's ability to significantly extend the corrected field of view, which is illustrated in Figure 2.6. Future plans for MCAO include development of operational MCAO for the 1.6 m New Solar Telescope (NST) at Big Bear Solar Observatory in collaboration with the New Jersey Institute of Technology and Kiepenheuer Institute in Germany. This activity is a pathfinder for the ultimate goal of integrating MCAO into the 4-m aperture ATST.

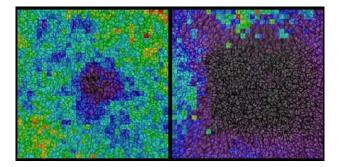


Figure 2.6. Residual image motion maps. Encoded in color and overlaid on the granulation image is the amount of residual image motion derived from analysis of imagery taken simultaneously with conventional AO (left) and MCAO (right). The MCAO was implemented with five "guide stars" and two deformable mirrors. Dark blue-purple colors indicate good correction of wavefront aberrations. The MCAO clearly extends the size of the corrected area on the Sun.

2.7 SOLIS VSM Milne-Eddington (ME) Data Inversions

SOLIS Vector Spectromagnetograph Milne-Eddington data inversions have been produced regularly and made available online to the solar community since April 1, 2009. In order to produce Milne-Eddington images, successful fringe removal algorithms were developed using observed polarization data to clean up the spectra. The first vector quick-look images processed in the pipeline using this code were made available via the NSO SOLIS Web page on December 30, 2008. Once the fringes were successfully removed, the SOLIS team converted the ME inversion code from a small field-of-view application into a full-disk, large field-of-view application. Codes for determining quiet-Sun profiles were developed and then optimized to decrease processing time. In addition, smear-fitting code was developed to determine the best value to use for smearing the quiet-Sun code for a best first with the data.

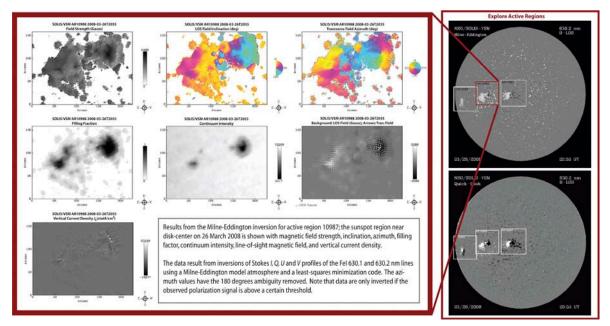


Figure 2.7. SOLIS VSM results from the Milne-Eddington inversion for active region 10987.

2.8 Facility IR Spectropolarimeter (FIRS) at the Dunn Solar Telescope

Observations of the static and dynamic properties of solar magnetic features in the photosphere and chromosphere can yield information critical to the ultimate resolution of a broad range of problems in modern solar physics research. For example, a complete, three-dimensional picture of the magnetic field, thermal, and dynamic properties of a sunspot should shed light on how sunspots are formed, how they maintain a quasi-static configuration against the highly dynamic plasma of the photosphere, and how the normal and inverse Evershed flows are driven. A time sequence showing the photospheric and chromospheric magnetic field evolution of a complex active region may finally allow us to identify the mechanisms that build up and release the magnetic energy which drives explosive flares and coronal mass ejections

The Facility Infrared Spectropolarimeter (FIRS) for the Dunn Solar Telescope is a new instrument specifically designed to address these important problems. It employs an achromatic reflecting Littrow spectrograph design to allow for simultaneous observations of photospheric and chromospheric spectral lines. A new multiple-slit design has been adopted to better utilize the modern large format detector arrays and to achieve a four-times enhancement of the system throughput when compared to conventional single-slit spectropolarimeters. The instrument is is now supported by NSO for visitor use.

In July 2009, FIRS PI Haosheng Lin and graduate student Sarah Jaeggli (U. Hawai'i, IfA) used FIRS to observe the first sunspot active regions (AR 11024) of the new solar cycle at three spectral lines (Fe I 630 nm, 1565 nm, Si I 1082.7 nm, and He I 1083.0 nm), simultaneously with the *Hinode* spectropolarimeter (SP). Preliminary analysis showed that FIRS and *Hinode*/SP produced effectively identical Stokes spectra at the Fe I 630 nm lines, demonstrating that the ground-based FIRS data can be supplemented with the seeing-free high-resolution data from *Hinode*/SP, or conversely, the scientific reach of the *Hinode*/SP instrument can be expanded with the multiple-height data from FIRS, greatly enhancing the value of the two instruments.

Study is now underway to use the data set to decipher the 3-D structure of the magnetic fields of AR 11024. The vector magnetic fields infrared at the two Fe line level have clearly shown the decrease of the magnetic field strength B as a function of height in the sunspot umbra. Intriguingly, however, significant differences in B in the penumbral regions were not observed, perhaps suggesting that the penumbrae are a thin layer in the solar atmosphere. This study is being expanded to include data from the Si I and He I lines which will provide more stringent constraint for the sunspot models.

2.9 Internal Solar Flows and the Extended Solar Minimum

Rachel Howe (NSO) has been comparing the evolution of the torsional oscillation during the current deep and extended solar minimum, preceding cycle 24, and the last minimum, 1995–1997, which preceded cycle 23. The torsional oscillation is a flow in the East-West direction that is slightly faster (about 5 meters per second) than solar rotation, and that migrates from the poles down to the Equator over a period of some 17 years. The active regions and sunspots occur on the boundary of the torsional oscillation flow and follow its migration in latitude. As seen in Figure 2.9, the torsional oscillation for the current minimum has taken about 2.5 years to migrate from latitude 35 degrees to latitude 25 degrees. This can be compared with the 1.5 years taken by the torsional oscillation from the previous cycle to cover the same range. The current minimum is also now about one year longer than the last one, so there is a correlation between the migration rate of the torsional oscillation and the length of the minimum. In addition, the torsional oscillation from the last cycle (23) has persisted at the Equator longer than that of the cycle before it (22). Finally, since the solar-activity level rose rapidly shortly after the torsional oscillation from cycle 23 reached 25 degrees latitude, the true onset of cycle 24 may occur in the near future. These observations indicate that some properties of the activity cycle may be predictable from the evolution of the torsional oscillation leading up to it. This result, published in *ApJ*, 701 (2009) L87-L90, was announced at the meeting of the June 2009 Solar Physics Division of the American Astronomical Society in Boulder, Colorado, and was the subject of a press conference that generated considerable interest among the media.

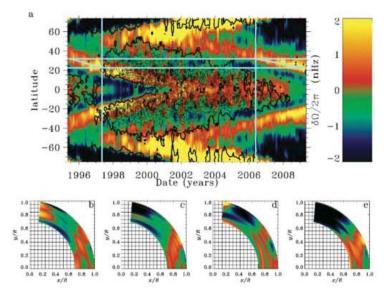
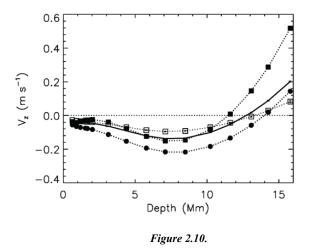


Figure 2.9. The evolution of the torsional oscillation (TO), a flow inside the Sun that migrates from the poles to the Equator during the course of the solar cycle. We have found that the TO for the current cycle, which appeared in 2003, is moving more slowly towards the Equator than it did for the previous cycle. The extra length of time is reflected in the extended minimum of the solar cycle that is ongoing. (a) Rotation-rate residuals at 0.99Ro from the Michelson Doppler Imager and GONG. Overlaid contours show the gross longitudinal magnetic field strength from Kitt Peak Vacuum Telescope/SOLIS, at 5 gauss intervals. The leftmost solid vertical light-blue line shows the date, 1997.3, at which the low-latitude flow configuration best matches that in the most recent (2009.2) data set, and the rightmost vertical line shows the date, 2006.4, where it best matches that in the earliest data set (1996.5). The horizontal lines show the respective location of the flow bands and the slanted lines schematically indicate the migration of the equatorward branch. The lower panels show 12-month averages of the rotation-rate residuals in the r, θ plane for epochs starting at (b) 1995.5, (c) 1996.3, (d) 2006.5, and (e) 2008.2.

2.10 Subsurface Flows and Emergent Magnetic Flux

Rudi Komm (NSO) has recently found a signature of emerging magnetic flux in the GONG++ subsurface flow maps. Figure 2.10 shows the average vertical velocity as a function of depth for 801 active regions classified in a variety of ways. The solid line shows the vertical velocity averaged over all of the regions and all of the observations. The filled squares show the vertical velocity for regions with emerging fluxthe 25 percent of regions with the highest increase in flux. Similarly, the filled circles are for regions with decaying flux — the 25 percent with the greatest decrease in flux. The open squares are for the remaining 50 percent of the regions. The plot shows that emerging flux is associated with strong upflows in the deeper layers (10-15 megameters), and weaker downflows near the surface. The decaying flux shows



the opposite: stronger downflows near the surface, and weak upflows at deeper depths. This is the first unambiguous indication of a subsurface effect arising from an emerging magnetic field.

3 SCIENTIFIC AND KEY MANAGEMENT STAFF

The NSO's strength lies in the quality of its scientific and key management staff. The scientific staff provides support to users, supports instrument development, conducts outreach, mentors graduate students and postdoctoral fellows, and organizes community workshops on critical areas of solar research and planning.

As described in Section 7.1 on NSO organization, many of the scientific and key management staff fulfill several functions, which is typical for a small organization such as NSO. In spite of this, the NSO continues to function smoothly. Up to now, the NSO has not implemented multiple-task time carding for its scientific staff. We will do so in FY 2010. This will be critical because of the need to clarify and separate any effort expended on ATST construction, since under MREFC rules, use of base-funded activities to support construction efforts is prohibited. On the other hand, NSO will use base supported activities to prepare for operations in the ATST era. These efforts include developing multi-instrument support techniques and data handling, establishing an ATST data center, and developing ATST second-generation capabilities and instruments, such as MCAO, that are not part of the construction baseline.

NSO scientific and management staff, as well as affiliated scientific staff, are listed below with their primary areas of expertise and key observatory responsibilities. Table 3.1 shows the NSO scientific staff FY 2009 estimates of how they divided their time for research, administration and/or management, instrument development, EPO activities, etc. Individual research and service plans for NSO scientific staff are contained in Appendix G.

3.1 Sunspot-Based Scientific and Key Management Staff

(*Grant-supported staff)

3.1.1 NSO Staff

David F. Elmore – Ground-based spectrograph and filter-based polarimeter development; ATST Instrument Scientist.

Steven Hegwer – Technical and Telescope Operations Manager; Optical Design; ATST Instrument Engineer.

Rex G. Hunter – Support Facilities and Business Manager, NSO budget management; ATST business support.

Stephen L. Keil - NSO Director; ATST PI; solar variability; convection.

Alexei A. Pevtsov – Solar activity; coronal mass ejections; solar magnetic helicity; SOLIS Program Scientist.

Thomas R. Rimmele – Solar fine structure and fields; adaptive optics; instrumentation; ATST Project Scientist; Dunn Solar Telescope Program Scientist; ATST/AO program lead.

Han Uitenbroek – Atmospheric structure and dynamics; radiative transfer modeling of the solar atmosphere; Ch., NSO/SP Telescope Allocation Committee; ATST Visible Broadband Imager PI.

Alexandra Tritschler – Solar fine structure; magnetism; Stokes polarimetry; ATST operations.

Friedrich Wöger – High-resolution convection; solar fine structure, convection; magnetic fields; ATST Data Handling Scientist.

3.1.2 Air Force Research Laboratory Staff at Sunspot

Richard C. Altrock – Coronal structure and dynamics.

K. S. Balasubramaniam – Solar activity; magnetism; polarimetry; ATST.

Richard R. Radick – Solar/stellar activity; adaptive optics.

S. James Tappin – Coronal mass ejections.

3.1.3 Postdoctoral Fellows

*Jose Marino – Wavefront correction; image restoration (located at University of Florida). *Nina V. Karachik –(New hire; started October 2009) Solar helicity and activity.

3.1.4 Thesis Students

Michael Kirk (New Mexico State University) – Flare prediction.

3.1.5 Active Emeritus Staff (not in residence at Sunspot)

Donald Neidig – Solar activity and flare prediction.
George Simon – Convection.
Jack Zirker – Solar prominences.
Jacques M. Beckers – Optical telescope design.
Raymond Smartt – Solar eclipses and coronal structure.

3.2 Tucson-Based Scientific and Key Management Staff

(*Grant-supported staff)

3.2.1 NSO Staff

Luca Bertello – (New hire, starts February 2010); SOLIS Data Scientist; solar vector magnetic fields, helioseismology.

Mark S. Giampapa – NSO Deputy Director; stellar dynamos and magnetic activity; asteroseismology; astrobiology; Ch., NSO/KP Telescope Allocation Committee; Ch., Scientific Personnel Committee; SOLIS PI.

Irene E. González Hernández – Local helioseismology; helioseismic holography; ring diagrams.

Frank Hill – Solar oscillations; data management; GONG Program Scientist; Associate Director for Synoptic Programs.

Rachel Howe - Helioseismology; the solar activity cycle; peak fitting.

John W. Harvey – Solar magnetic and velocity fields; helioseismology; instrumentation; SOLIS Project Scientist.

Shukur Kholikov – Helioseismology; data analysis techniques; time-distance methods.

John W. Leibacher – Helioseismology; atmospheric dynamics.

George Luis – GONG Program Manager.

Matthew J. Penn – Solar atmosphere; solar oscillations; polarimetry; near-IR instrumentation; Co-Site Director, NSO REU/RET Program; McMath-Pierce Facility Scientist; ATST near-IR.

Priscilla Piano – Director and Tucson site support; Administrative Manager, Director's Office and NSO/Tucson site.

Kim V. Streander – Technical Program and Telescope Manager; SOLIS Program Manager.

Jeremy J. Wagner – ATST Project Manager.

Robert S. Upton – ATST Wavefront Correction scientist.

3.2.2 Postdoctoral Fellows

*Walter W. Allen, Jr. – (New hire; started August 2009) Solar physics; waves; supergranulation. Olga Burtseva – Time-distance analysis; global helioseismology; leakage matrix.

***Brian J. Harker-Lundberg** – Stokes spectropolarimetry of the photosphere; Stokes inversion techniques for inferring vector magnetic fields; automated tracking and classification of sunspot and active region structure; parallel processing computational techniques for data reduction.

*William H. Sherry – Evolution of stellar activity; protoplanetary disks.

3.2.3 Thesis Students

Matthew Richardson (Fisk University) – Helioseismology. Thomas Schad (University of Arizona) – IR spectropolarimetry.

3.2.4 Grant-Supported Scientific Staff

*Michael Dulick – Molecular spectroscopy; high-resolution Fourier transform spectrometry.

*Rudolph W. Komm - Helioseismology; dynamics of the convection zone.

*Gordon J. D. Petrie – Solar magnetism; helioseismology.

*Sushanta C. Tripathy – Helioseismology; solar activity.

*Roberta M. Toussaint - Helioseismology; image calibration and processing; data analysis techniques.

3.2.5 Active Emeritus Staff in Tucson

William C. Livingston – Solar variability.

Harrison P. Jones – Solar magnetism and activity.

	Table 3.1	NSO Scientif	ic Staff Est	timated Perce	ent FTE by A	ctivity (FY	2009)	
				Project	User	Internal	External	
Name	Adm/Mgt ¹	Research ²	EPO ³	Support	Support	Comm.	Comm.	TOTAL
*Allen, W.F. (N/A)								0.0
*Bertello, L. (N/A)								0.0
Burtseva, O.		86.0		4.0	4.0		6.0	100.0
Dulick, M.					100.0			100.0
Elmore, D.F.		12.0	12.0	50.0	8.0	2.0	8.0	92.0
Giampapa, M.S.	70.0	8.0	11.0	5.0		4.0	2.0	100.0
González Hernández , I.	1.0	60.0	6.0	15.0	15.0	1.0	2.0	100.0
Harker-Lundberg, B.J.		100.0						100.0
Harvey, J.W.	2.0	3.0	1.0	43.0	42.0	4.0	5.0	100.0
Hill, F.	70.0	10.0	5.0	9.0		1.0	5.0	100.0
Howe, R.		80.0		10.0	5.0		5.0	100.0
Jain, K. (50%FTE)		49.0					1.0	50.0
*Karachik, N.V. (N/A.)								0.0
Keil, S.L.	35.0	5.0	5.0	45.0		5.0	5.0	100.0
Kholikov, S.S.		70.0		15.0	15.0			100.0
Komm, R.W.		90.0		5.0	5.0			100.0
Leibacher, J.W.		40.0	10.0	30.0		11.0	9.0	100.0
Penn, M.J.	3.0	50.0	15.0	5.0	10.0	10.0	7.0	100.0
Petrie, G.J.D.		50.0	15.0	30.0			5.0	100.0
Pevtsov, A.A.	32.0	21.0	20.0	10.0	5.0	2.0	10.0	100.0
Rimmele, T.R.		5.0	9.0	68.0	10.0	4.0	4.0	100.0
Sherry, W.H.		94.0	3.0			3.0		100.0
Toussaint, R.M.		4.0	1.0	48.0	47.0			100.0
Tripathy, S.C.		96.0					4.0	100.0
Tritschler, A.		36.0	8.0	17.0	20.0	18.0	1.0	100.0
Uitenbroek, H.		50.0	10.0	10.0	10.0	5.0	15.0	100.0
*Upton, R.S. (N/A)								0.0
Woeger, F.		35.0	10.0	25.0	20.0	10.0		100.0

*New staff; statistics unavailable.

¹Administrative and/or Management Tasks

²Research, including participation in scientific conferences

³Educational and Public Outreach

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

Fulfilling NSO's mission of providing observation opportunities to the scientific community and training the next generation of solar researchers requires that first-class ground-based solar facilities remain available on a continuous basis. Thus NSO has developed a plan with the flexibility to transition from current facility operations to the period when new facilities are in place. 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 U.S. and international solar research. The NSO telescope upgrade and instrument program is guided by the scientific and technical imperatives for the new ATST.

NSO telescopes remain extremely productive and are among the most useful solar telescopes in the world. Although the major NSO telescopes are four or more decades old, they still play a key role in support of U.S. and international solar research. The NSO telescope upgrade and instrument development program is guided by the scientific and technical imperatives for a new ATST. Consequently, telescope and instrument upgrades and operations are reviewed and supported on the basis that they serve as necessary preludes to the ATST initiative, while concurrently serving the needs of the scientific community. Both as a necessary prelude to the ATST and as indispensable facilities for current research in solar physics, NSO operation of the Dunn Solar Telescope and the McMath-Pierce Solar Telescope will continue until the ATST is commissioned.

Assuming an FY 2010 start for ATST construction, we expect to achieve full scientific operations in 2017. Until the ATST is online, the solar community relies on the DST for high-resolution spectropolarimetry and the McMP for high-resolution spectropolarimetry and imaging infrared observations beyond two microns. Over the past few years, NSO has been upgrading existing instrument and data handling systems in order to continue operations at the DST and McMP until a smooth transition to the ATST can be affected. Current upgrades are performed with ATST requirements in mind and in such a way as to test ATST concepts such as instrument and data interfaces and software architecture.

4.1 Dunn Solar Telescope (DST)

The 76-cm Richard B. Dunn Solar Telescope, located on Sacramento Peak, is a diffraction-limited solar telescope with strong user demand and excellent scientific output. It has two identical AO systems—well matched to the seeing conditions at the DST—that feed two different instrument ports. These ports accommodate a variety of diffraction-limited, facility-class instrumentation, including the Diffraction-Limited Spectro-Polarimeter (DLSP), and the Spectro-Polarimeter for Infrared and Optical Regions (SPINOR), the Interferometric BIdimensional Spectrometer (IBIS), the Facility Infrared Spectrograph (FIRS), the Rapid Oscillations of the Solar Atmosphere (ROSA) imaging system, and a high-speed speckle system. Many of these instruments are used simultaneously, providing multi-spectral imaging and spectroscopy at several heights in the solar atmosphere. This suite of post-focus instrumentation continues to make the DST the most powerful facility available in terms of post-focus instrumentation.

In addition to supporting the solar community, and the science discussed in Section 2, the DST supports observations that drive ATST high-resolution requirements at visible and near-infrared wavelengths, and help to refine ATST science goals. The DST also supports the development of future technologies such as multi-conjugate AO (MCAO). Several successful on-sky MCAO experiments were recently performed at the DST (see Section 2.6). The DST supports the U.S. and international high-resolution and polarimetry communities and is often used in collaboration with space missions to develop global pictures of magnetic field evolution. While competing European telescopes have emerged, they have not

supplanted the need for the DST. Many Europeans still compete for time on the DST and provide instruments, such as IBIS (Italy) and ROSA (Northern Ireland, UK), that are available to all users. The 1-m Swedish Solar Telescope (SST) is providing high-resolution imaging and polarimetry with a geographic separation of seven hours from the DST. The geographic separation enables collaborations that extend the ability to follow magnetic evolution over longer periods, substantially enhancing the probability of observing the build-up and triggering of solar activity events. The DST will continue to play the major role in supporting U.S. high-resolution spectropolarimetry and in the development of instruments needed for progress in this important field. These instruments will be the backbone of the ATST.

The NSO instrumentation program is focused on the development of enabling technologies that will be central to the ATST and a strong program of understanding solar magnetic variability. The primary areas of observational capabilities at the DST are high-resolution spectroscopic and spectral-imaging vector polarimetry in the visible and near-IR. Instrument development and scientific applications in these areas rely on the unique capabilities of the DST.

4.1.1 Adaptive Optics and Wavefront Sensing

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

The NSO high-order AO development was brought to a successful completion. The AO project, carried out in primary partnership with the New Jersey Institute of Technology (NJIT), has resulted in two fully operational AO systems at the DST. A similar system was deployed at Big Bear Solar Observatory (BBSO). The NSF sponsored this project within the Major Research Instrumentation (MRI) program with substantial matching funds from the participating partner organizations, which include the NSO, NJIT, Kiepenheuer Institute in Germany, and the Air Force Research Laboratory. A joint NSO/NJIT follow on effort to develop a scaled up system (349 actuators compared to the 97 actuators for the current system) for the BBSO New Solar Telescope is underway. This effort is serving as a prototype for scaling up the current systems to meet ATST requirements (a 1300 actuator system).

The current AO systems and the development of the new BBSO system serve as proofs-of-concept for a scalable AO design for the much larger 4-m ATST. The DST systems are serving as test beds for the development of the ATST AO system. For example, the project is testing reconstruction algorithms needed for the ATST AO, where the pupil on the deformable mirror will rotate with respect to the wavefront sensor.

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

With the completion and deployment of the high-order AO systems, technical efforts of the AO project are now focused on the development of multi-conjugate adaptive optics. The Sun is an ideal object for

the development of MCAO because solar structure provides the "multiple guide stars" needed to determine the wavefront information in different parts of the field of view. The NSO system is one of the first successful on-sky MCAO experiments (the Kiepenheuer MCAO system being the other). Current MCAO work focuses on evaluating and improving the system performance and making comparisons with model predictions. The major challenge is to develop and implement efficient control algorithms and find optimum and practical positions for the deformable mirrors. More wavefront sensor subfields also may have to be added. The solar MCAO experience will be very valuable to the entire astronomical community. The NSO's main goal, however, is to develop MCAO technology for the ATST.

4.1.2 Diffraction-Limited Spectro-Polarimeter (DLSP)

The Diffraction-Limited Spectro-Polarimeter is fully integrated with one of the high-order AO systems (Port 2). A 1 Å K-line imaging device and a high-speed 2K × 2K G-band imager with speckle reconstruction capability as well as a slit-jaw imager have been integrated with the DLSP and high-order AO as permanent capabilities. A diffraction-limited resolution mode (0.09 arcsec/pixel, 60 arcsec FOV) and a medium-resolution mode (0.25 arcsec/pixel, 180 arcsec FOV) are available. The Universal Birefringent Filter (UBF) can be combined with the DLSP/imaging system. The full-up instrumentation set is now available for users. There are plans to make the reduced data available via the Virtual Solar Observatory.

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

4.1.3 Facility Infrared Spectropolarimeter (FIRS)

This is a collaborative project between the National Solar Observatory 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/MRI-funded project. This instrument takes 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. The diffractionlimited 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), a vital feature for studying dynamic solar phenomena such as flares. The highorder Echelle grating allows for simultaneous multi-wavelength observations and thus 3-D vector polarimetry. The detector is a $1K \times 1K$ IR camera synced to a liquid crystal modulator. FIRS is now a fully supported user instrument.

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

SPINOR is a joint HAO/NSO program to replace the existing advanced Stokes polarimeter (ASP) at the Dunn Solar Telescope with a much more capable system. The ASP has been the premier solar research spectropolarimeter for the last decade. Its ability to explore new spectral lines and to observe in multiple lines simultaneously is still unique. The ASP wavelength range was restricted to the visible, limiting its ability to sample new solar diagnostics, and its hardware is becoming out-dated and difficult to maintain. SPINOR extends the wavelength of the ASP from 750 nm to 1600 nm with new cameras and polarization optics, provides improved signal-to-noise and field-of-view, and replaces obsolete computer equipment. Software control of SPINOR is now part of the DST camera control and data handling system.

SPINOR, along with IBIS, are the primary instruments for joint observations with *Hinode* as they will also be for the Solar Dynamics Observatory after its launch in February 2010. SPINOR and IBIS augment capabilities for research spectropolarimetry at the DST and extend the lifetime of state-of-the-art research spectropolarimetry at the DST for another decade.

4.1.5 Interferometric BIdimensional Spectrometer (IBIS)

IBIS is an imaging spectrometer built by the solar group of the University of Florence in Arcetri, Italy. IBIS delivers high spectral resolution (20 mA), high throughput, and consequently high cadence. In collaboration with NSO and the High Altitude Observatory, the Arcetri group has recently upgraded IBIS to a vector polarimeter. The wavelength range of IBIS extends from visible to near-IR and allows spectroscopy and polarimetry of photospheric and chromospheric layers of the atmosphere. NSO has a Memorandum of Understanding with the University of Florence for continued operation and support of IBIS at the DST.

4.1.6 Replacements and Upgrades

Critical Hardware

Given the finite time frame for DST operations, replacement and upgrades of hardware and software are limited to the necessary minimum. The Critical hardware upgrade (CHU) reduces 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 are limited to supporting existing capabilities rather than offering enhanced capabilities.

Storage Area Network (SAN) Upgrade

The high data volumes produced by existing and new instrumentation such as IBIS, SPINOR, FIRS, and ROSA, an instrument to measure Rapid Oscillations in the Solar Atmosphere, required an expansion in data storage and handling capabilities at the DST. The DST data handling system (0.5 TB) was near its maximum capacity. The IBIS camera upgrade alone pushed storage requirements and bandwidth well beyond existing capacity. In the past, the standard storage media used to transfer data to users was DLT tape. The DST DLT tape drives had become obsolete, downtime was increasing, and DST users expressed a strong preference for using hard drives as storage media. Hence, the data handling system has been expanded to 4 TB of storage and the existing DLT storage media replaced with removable hard drives.

4.1.7 Current and Future Use of the DST

NSO users and staff will continue to vigorously pursue the opportunities presented by high-resolution, diffraction-limited imaging at the DST, with a goal of testing models of magnetoconvection and solar magnetism, while refining ATST science objectives and ensuring the growth of expertise needed to fully exploit ATST capabilities. The advent of high-order AO has increased the demand for DST time and has given ground-based solar astronomy the excitement shared by space missions.

When ATST is complete, the high-resolution capabilities of the DST will be surpassed and NSO will cease operations and either close the DST or, preferably, find a group or groups interested in exploiting the DST for their own uses.

4.2 McMath-Pierce Solar Telescope (McMP)

The McMath-Pierce Solar Telescope on Kitt Peak is the largest unobstructed-aperture optical telescope in the world. It is 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. A new low-order AO system provides diffraction-limited imaging and spectroscopy at these infrared wavelengths. Coupled with the InSb-based detector of the NSO Array Camera (NAC), the McMP is producing the best mid-infrared solar observations ever achieved.

Infrared polarimetry and infrared imaging developed at NSO have been combined with the McMath-Pierce Telescope to reveal a ubiquitous presence of weak fields associated with turbulent convection at the solar surface that could play an important role in solar magnetic flux loss and heating of the outer solar atmosphere. Other observations with these systems have measured chromospheric magnetic fields and may provide the opportunity to directly observe coronal magnetic fields. The NAC will be used to test the theory that outlines how MHD waves decouple when propagating through the region where the plasma beta equals unity, the so-called magnetic transition region.

Much of the infrared spectrum is still barely explored, especially in flares, sunspots, and the corona. The McMath-Pierce telescope and the NAC have begun to address these questions with new observations of a powerful X1.8 flare in the infrared He I line at 1083 nm, and new observations of the CO lines at 2330 nm at the solar limb. Further studies will be used to develop techniques and science questions that will continue to refine the ATST IR capabilities.

The NAC will conduct spectropolarimetry of atomic lines near 4 microns. Particular lines from Si I and Fe I will be used to probe the photospheric magnetic fields, and Ca I and Mg I lines will be used to probe the chromosphere; these lines will provide magnetic sensitivity not possible with spectral lines in the visible or near-infrared. Weak magnetic fields and small changes in the magnetic fields with time will be examined in the quiet Sun and in sunspots and solar active regions. Finally, the cool solar temperature minimum will be probed with a variety of molecular lines including CN, CO and H₂O.

The Fourier Transform Spectrometer (FTS), located at the McMP Facility, is a unique national resource in wide demand by atmospheric physicists and chemists, as well as astronomers. The FTS is a highly stable, Michelson interferometer that is able to simultaneously achieve high spectral resolution, excellent signal-to-noise ratio, and wide bandpass. The FTS is thus able to produce high-quality measurements of line positions, strengths, and widths. The McMath-Pierce FTS is a multi-disciplinary facility that is utilized for research programs in laboratory spectroscopy, atmospheric sciences, and solar physics. The FTS produces widely-used infrared solar atlases and is the only facility that completely resolves atomic and molecular lines at wavelengths out to 20 microns. The McMath-Pierce facility has been designated as an official complementary site for the Network for the Detection of Stratospheric Change (NDSC). The Earth atmospheric measurements that are made at this facility are included in the NDSC archive. A consortium has formed that has supported the upgrade of the FTS and will help support its use.

4.2.1 NSO Array Camera (NAC)

Because the McMath-Pierce does not have an entrance window, it has access to the solar infrared spectrum beyond 2.5 microns. A major focus of the NSO Tucson in-house instrumentation program has been on the large-format NSO Array Camera, which is now observing wavelengths from 1 to 5 microns with imaging, spectroscopy, and spectropolarimetric modes. The NAC represents a significant improvement over previous NSO IR cameras. New types of scientific observations, including flare emission and rapid flows associated with an X1.8 flare, limb emission and chromospheric dynamics observed with CO absorption lines, and high-resolution AO-corrected imaging observations of granulation from 1000 to 4700 nm have been made. The NAC is being used to make sensitive magnetic field measurements in sunspot umbra, for studies of molecular line formation, and it is planned to be used for upcoming polarimetric observations from 3 to 5 microns. In addition to these PI-driven studies, NSO has migrated other observing programs to this camera, using infrared spectral diagnostics where previously visible spectral lines were used.

Implementing and demonstrating the scientific value of a fast, large-format infrared camera is an important component of NSO's preparation for the IR-capable ATST. The regular operation of the large-format, advanced IR instrument at the McMath-Pierce Solar Telescope facility will offer the most advanced research capability in the mid-IR for solar physics in the world today.

4.2.2 Integral Field Unit (IFU)

A grant from the NSF Advanced Technology Instrumentation (ATI) program has funded development of a state-of-the-art, all-reflective image slicer integral field unit. The IFU was developed for AO-corrected infrared observations with the McMath-Pierce vertical spectrograph. D. Ren (California State U. North-ridge) and C. Keller (U. of Utrecht) were co-investigators on this project. The IFU divides 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 can 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 mounts in the optical beam between the current AO system and McMP spectrograph slit.

The IFU has been dedicated as a user instrument at the McMP in FY 2010.

4.3 Global Oscillation Network Group (GONG)

The Global Oscillation Network Group program is an international, community-based program that studies the internal structure and dynamics of the Sun by means of helioseismology—the measurement of resonating acoustic waves that penetrate throughout the solar interior—using a six-station, world-circling network that provides nearly continuous observations of the Sun's five-minute oscillations. The instruments obtain 2.5-arcsecond pixel velocity, intensity, and magnetic-flux images of the Sun every minute, with an approximately 90% duty cycle, enabling continuous measurement of local and global helioseismic probes from just below the visible surface to nearly the center of the Sun. The high-cadence, high-sensitivity magnetograms, and near-real-time seismic images of the farside of the Sun are now available.

GONG's science goals are to study the steady and time-varying temperature, composition, and rotation of the solar interior; to characterize the subsurface properties of the solar cycle on large and small scales; to explore the nature of individual active regions; to obtain images of the far side of the Sun to support a space weather predictive capability; and to provide continuous high-time-cadence and coverage, lownoise and precise magnetograms to support non-helioseismic studies such as the formation of coronal holes and coronal mass ejections, extrapolating the temporally well-sampled photospheric field, and examining the inferred coronal field's evolution. Results to date have substantially advanced the knowledge of solar internal structure from the core to the surface, and measurements are now being taken of significant structural variations and flows through the solar magnetic activity cycle, in addition to variations on shorter time scales. An example of the cycle-related variations is the sub-surface evolution of the torsional oscillation, an east-west oriented band of plasma that is moving slightly faster than the surface rotational velocity and that is spatially correlated with the surface activity. GONG observations have revealed that the torsional oscillation is not confined to the surface, but instead extends downward through the convection zone, and can be seen to rise to the surface as the cycle progresses. On shorter time scales, GONG has revealed the presence of twisting tornado-like motions below large active regions that produce many X-class flares. The temporal variation of the amplitude of the twisting motion appears to predict the onset of activity, and this has now been demonstrated to provide a useful space weather predictive capability.

In addition to helioseismology science products, GONG is now providing an unprecedented and unique dataset to the solar physics community in the form of high-cadence (one per minute) full-disk longitudinal magnetograms that are continually obtained around the clock. Ten-minute averages of these images are

returned to Tucson in near-real time, and extrapolations of the surface field into the corona are automatically generated and placed on the Internet on an hourly basis. This new dataset is being used by NASA missions, such as STEREO and *Hinode*, and is being incorporated into solar wind models for space weather. The continual high cadence of the observations has also revealed flare-related changes in the magnetic field, the presence of a rapidly varying horizontal component to the magnetic field, and curious anisotropies in the behavior of the *p* modes near sunspots.

NSF, through the NSO, has made a large investment in GONG to upgrade to a higher resolution capable of subsurface imaging, imaging of the far side of the Sun, and to greatly increase the resolution of solar velocity and magnetic structures below the solar surface. Such data are critical to understanding the generation of solar magnetic fields. A substantial fraction of the helioseismic investigators use GONG as a primary data source. When available, the supplemental data from space missions helps confirm GONG results and vice versa. Having two instruments enhances the reliability of deducing subsurface features. To assume GONG can be replaced by a limited duration space mission such as SDO is unwise for several reasons, including potential failure, degradation of detectors, no confirmation of results, and lack of continuity between mission, to name a few. To assume that helioseismology is no longer of use or important is like saying that the need to study stars and stellar systems is no longer necessary because enough is known. Given the value of GONG to the space weather community, NSO is seeking operational funding. Recently, the U.S. Air Force provided funds to add an H-alpha capability to GONG as a precursor to providing operational funding. This system is now under development and will be deployed in the spring of 2010. However, there is no guarantee that the amount of operational funding that will be provided will be sufficient to satisfy the Senior Review recommendation.

The Senior Review recommendations linked the decommissioning of GONG to the availability of the Solar Dynamics Observatory. NSO will carefully monitor the progress of that mission to understand the potential timing of such a decommissioning in order to develop a back-up plan should outside funding not materialize. NSO will develop options for potential consideration by the NSF and continue to negotiate with NSF regarding additional support for this impressive scientific bang-for-the-buck program. Finally, the helioseismology community is providing views on the overall progress in the field of helioseismology for discussion purposes for the current Decadal Survey.

4.4 Synoptic Optical Long-Term Investigations of the Sun (SOLIS)

The SOLIS project records optical measurements of processes within the solar photosphere and chromosphere, the study of which requires well-calibrated, sustained observations over a long time period (~25 years). The primary and unique SOLIS instrument is the vector spectromagnetograph (VSM), which was installed on Kitt Peak in April 2004 after seven months of preliminary observing at a temporary site in Tucson. Regular observations from Kitt Peak have been underway since May 2004, with several data products available on the Internet. The other two SOLIS instruments are the integrated sunlight spectrometer (ISS) and the full-disk patrol (FDP) imager. The ISS has been operating daily on Kitt Peak since December 2006.

The emphasis in the SOLIS program is on moderate to large spatial scale activity over the course of the solar activity cycle. Other facilities deal more effectively with small spatial scales and short observing campaigns. This emphasis on regular cadence observations for long sustained periods defines the most productive science goals for SOLIS. The same strategy governed the science achieved by the VSM's highly-successful predecessor, the NSO Kitt Peak Vacuum Telescope, and the ISS' predecessor synoptic programs using the Evans and McMath-Pierce facilities. The archives of these earlier programs are still in heavy use and each has produced distinguished science results. The FDP was purposely given lower priority with respect to the VSM and ISS due to resource constraints and its non-uniqueness. The FDP is now being completed in Tucson prior to its move to Kitt Peak in 2010.

Current emphasis is on completion and stable operation of SOLIS. A large number of unique full-disk vector magnetic field observations have been accumulated since September 2003. Their calibration and inversion to produce vector magnetograms was recently improved and they are now being made available on the Web. SOLIS VSM observations have shown a wealth of interesting new phenomena. In addition to the full-disk line-of-sight and full-disk vector magnetograms, quick-look and detailed vector magnetograms of selected active regions are available online.

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

4.4.1 Summary of the Status of SOLIS and Data Products

Vector Spectromagnetograph (VSM). The VSM provides full-disk longitudinal and vector magnetograms in the 630.2 nm line, chromospheric 854.2 nm longitudinal magnetograms, full-disk chromospheric 1083.0 nm equivalent-width images and the location of coronal holes as extrapolated from the 1083.0 nm maps. Synoptic Carrington rotation maps are provided for the 630.2 nm longitudinal magnetograms, 1083 nm helium chromosphere and extrapolated coronal hole location.

In January 2009, then SOLIS Program Scientist Aimee Norton took a faculty position at James Cook University in Townsville, Australia and subsequently was retained as a consultant to NSO at a 20% level. This change in staffing, along with the year-long open SOLIS data scientist position, required additional efforts from the software engineering staff to modify existing reduction code, maintain data quality, and fulfill data requests. On April 1, 2009, NSO announced that inverted vector magnetic field data from the SOLIS VSM instrument are available on the SOLIS Web site (*http://SOLIS.nso.edu/*). Both full-disk data and smaller field-of-view data containing active regions are available on the same day as the observations. Also available are a sample of data from March 2008 containing several active regions near the equator. Milne-Eddington (ME) inversions of vector observations taken since 2003 will be produced as time and personnel resources permit.

Full Stokes processing has now been running regularly in the pipeline with Quick-Look and Milne-Eddington images appearing (nearly) daily on the NSO Web site. In addition, several working environments suitable for reprocessing have been set up in order to more easily accommodate reprocessing requests from the solar community. Ways to expedite reprocessing have been identified and are gradually being implemented. A SOLIS 'dashboard' Web page has been developed to monitor what observations and processing have succeeded, failed, or are in process.

The release of inverted vector magnetic field data from the SOLIS VSM initiated constructive critiquing within the solar community. In particular, concerns were expressed regarding 1) a need to adjust the gray scale when displaying the Milne-Eddington full-disk images on the Web; 2) apparent 'rings' around active regions when displaying the line-of-sight field inclination; and 3) a desire to see a comparison between data taken with the VSM and *Hinode*.

Recent improvements to the Milne-Eddington inversion and plotting routine have greatly improved the appearance of the full-disk ME images on the Web. The field strength estimate returned by the ME

inversions was improved in areas outside sunspots by using the quick-look field estimates as an initial guess.

At the suggestion of the NSO Users' Committee, Jack Harvey found an existing data set that could be used for comparing inversion techniques between the SOLIS VSM and *Hinode*. A preliminary comparison between the two data sets shows remarkable similarities when considering the different image resolutions and an approximate 6.5-hour time difference. Additional data sets and analyses were compared during an October 2009 meeting of the Vector Magnetogram Comparison Group.

Integrated Sunlight Spectrometer (ISS). The ISS is making daily observations at the following wavelengths: 388.4 nm, 393.4 nm, 396.8 nm, 538.0 nm, 539.4 nm, 656.3 nm (H-alpha), 854.2 nm, and 1083.0 nm. Calibrated SOLIS ISS spectra and parameter time-series data are available publicly at *http://SOLIS.nso.edu*. Ca II H and K and He I 1083.0 nm spectra recorded by the ISS are now available daily as both FITS-formatted data and JPEG image files. Various Ca II K-line parameter time series data are also available as text-formatted data and JPEG image files.

Fluxes were normalized to reference values in the Fourier Transform Spectrometer flux atlas. ISS observations are spatially unresolved, which means that the Sun is observed as a star. Scientists will use the data taken with the ISS to understand how the solar cycle modulates the energetic output of the Sun as a function of wavelength, among other applications. For example, the daily record of 393.4 nm suggests that a minimum of emission was reached in about a year before the sunspot cycle minimum.

The ISS data calibration method was compared to that of the McMath-Pierce Solar Telescope when analyzing data taken simultaneously with both instruments. It was determined that if the two-point ISS calibration method was applied to the McMath-Pierce data set, then there is virtually exact agreement between the K-line parameters. These spectral lines correspond to wavelengths Bill Livingston (NSO) has used since 1975 to monitor the solar cycle using the McMath-Pierce spectrometer.

Full-Disk Patrol (FDP). The Full-Disk Patrol will record full-disk intensity images of the Sun using filtered portions of chromospheric and photospheric spectrum lines considered 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 completed. The system has been aligned up to the final beam splitter and has had the mechanism motors tuned for reliable operation. Several VSM electrical power supply failures in the past year have temporarily required taking parts out of the FDP to support observations with the VSM. These components have since been replaced and spares purchased. However, there are VME boards within the VSM and FDP that are no longer available but mission critical. It was decided that if the data acquisition system for the FDP was upgraded to the VSM design, then at least two VME boards could be retained as spares for the VSM. This design change alone will require at least four additional months of effort. In addition to completing the guider design, calibration and data processing algorithms are still 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.

4.4.3 SOLIS Instrument Upgrades and Hardware Replacement

The original vendor for the SOLIS VSM cameras defaulted on its contract, and the project was forced to install interim cameras that were slower, noisier, and had lower resolution than originally planned. This prevented the VSM from achieving its design performance. Fortunately, new cameras have recently become available with characteristics very similar to the original design. Three cameras (one spare) have been purchased from Sarnoff Corp. and modified to better meet the VSM scientific requirements. Work

on a new data acquisition system (DAS) that is compatible with the high-speed Sarnoff cameras is progressing well.

There is great community interest in obtaining chromospheric vector magnetic field measurements. This will require a new polarization modulator package and replace the current line-of-site magnetic field measurement. Due to current observational scheduling with support of *Hinode* and STEREO, it is anticipated that this task should be undertaken during the first quarter of FY 2010, in time to support the Solar Dynamics Observatory. Also, we are investigating the replacement of the current photospheric modulator package with a thermally stable, achromatic, large-aperture rotating modulator similar to the unit used in *Hinode*. Vendors currently are available who can fabricate the optical and mechanical components to meet the stringent scientific requirements of SOLIS.

Replacing the current processing machines with more reliable hardware is a high priority. In addition, the Storage Area Network (SAN) servers are currently without a spare. The function of these machines is critical to the operation of SOLIS and a phased replacement or upgrade is part of the long-range operational plan.

4.5 Evans Solar Facility (ESF)

The Evans Solar Facility provides a 40-cm coronagraph as well as a 30-cm coelostat. The Evans coronagraph is the most thoroughly instrumented in the world. As a result of insufficient funds, NSO no longer provides general user support at the ESF. The Air Force group at Sacramento Peak provides support for their program that uses the ESF 40-cm coronagraph. The coelostat is used in the NSO synoptic Ca II K-line monitoring program. This program will be discontinued once the cross-calibration with the SOLIS ISS has the opportunity to see the rise in chromospheric emission of the current solar cycle. SOLIS and ISOON have replaced the spectroheliogram capability of the ESF with full-disk imaging. The Air Force group provides funding for a part-time observer and provides NSO with funds for minimal maintenance. The High Altitude Observatory is developing an instrument for the ESF for measuring prominence magnetic fields and will provide support for its operation.

4.6 Digital Library

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic datasets (daily solar images from SOLIS, FTS data, and a portion of the Sacramento Peak spectroheliograms) over the Internet to the research community. Since the inception of the Digital Library in May 1998 up until September 30, 2009, more than 18.7 million science data files have been distributed, and more than 20,000 unique computers have accessed the system. These figures exclude any NSO or NOAO staff members. The holdings of the NSO Digital Library are currently stored on a set of RAID5 disk arrays and are searchable via a Web-based interface to a relational database. A new higher-capacity storage system is now being installed. This system, named */newsolarch/* (for SOLIS, or solar archive), also holds the Digital Library is fully supported by non-NSO funds, and is an important component of the Virtual Solar Observatory.

Key: DST = Dunn Solar Telescope HT = Hilltop McMP = McMath-Pierce Solar		lar Facility GONG = Global Oscillation Network Group KPST = Kitt Peak SOLIS Tower McMPE = McMath-Pierce East Auxiliary Telescope
Instrument	Telescope	Comments/Description
NSO/Sacramento Peak – OPTIC	AL IMAGING & S	PECTROSCOPY
High-Order Adaptive Optics	DST	60 - 70-mode correction
Interferometric Bidimensional Spectrometer (IBIS)		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 < 500,000, 300 nm - 2.5 μm
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies
Littrow Spectrograph	ESF	R <u><</u> 1,000,000, 300 nm - 2.5 μm
Various CCD Cameras	DST	380 - 1600 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
NSO/Sacramento Peak – IR IMA	GING & SPECTR	OSCOPY
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 & S	SPECTROSCOP	ſ
SOLIS Vector Spectromagnetograph	KPST	1083 nm: Stokes I, 2048 \times 1.0 arcsec, 0.35-sec cadence 630.2 nm: I, Q, U, V, 2048 \times 1.0 arcsec, 0.7-sec cadence 630.2 nm: I & V, 2048 \times 1.0 arcsec, 0.35-sec cadence 854.2 nm: I & V, 2048 \times 1.0 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 μm, R <u><</u> 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 \times 1024, direct imaging, and full Stokes polarimetry from 1- 2.2 μm
CCD Cameras	McMP	380 - 1083 nm, up to 1024 \times 1024 pixels
IR Adaptive Optics	McMP	1 – 12 μm
Stellar Spectrograph	McMP	380 – 1083 nm, R <u>≤</u> 10⁵
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-SITI	E, HELIOSEISMO	DLOGY NETWORK
Helioseismometer & Magnetograph	California, Hawaiʻi,	2.8-cm aperture; imaging Fourier tachometer of
	Australia, India, Spain, Chile	676.8 nm Ni I line; 2.5 arcsec pixels; 1-min. cadence.

5 INITIATIVES

The introduction of novel, post-focus instrumentation and adaptive optics has greatly enhanced the capabilities of the solar telescopes of NSO, thereby enabling whole new areas of scientific inquiry, especially in high-resolution and infrared observations of the Sun. These new results, combined with improved modeling, have shown that advances in spatial, temporal, and spectral resolution are required to accurately measure fine-scale, rapidly changing solar phenomena and to test the advances in our theoretical understanding. Increasing the number of photons collected over the short evolutionary times of solar features is needed for making accurate polarimetric observations. Meeting these challenges requires a new, large-aperture solar telescope.

5.1 Advanced Technology Solar Telescope (ATST)

The FY 2008 annual report described the progress of a community-wide project to develop the Advanced Technology Solar Telescope—the next generation, facility-class telescope to advance high-resolution solar physics and the measurement of solar magnetic fields. What follows is an update of the ongoing ATST design effort as well as the construction phase proposal review.

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

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

5.1.1 ATST Science Working Group (SWG)

Current membership of the Science Working Group can be found at *http://atst.nso.edu/swg-/members.html*. The SWG met September 9-11, 2009 in Boulder, Colorado. The SWG congratulated the ATST project team for the successful completion of the D&D phase of the ATST and was ecstatic about the imminent start of the construction phase of the project. The SWG re-emphasized the importance of realizing the tremendous scientific potential of the ATST by sustaining an adequate instrumentation systems effort that is commensurate with the ATST science mission. The SWG found that adequate detectors that meet the polarimetry requirements are an integral part of the instrumentation effort.

The SWG reviewed science use cases for first-light instrumentation and how they have been used to develop the Operations Concept Definition document (OCD). Draft science use cases were first laid out in the Science Requirements Document (SRD) and reflected in the science section of the ATST construction proposal. The ongoing effort is to flesh out in more detail the operational needs, while taking into account progress in solar physics, and to help fill in details for telescope and instrument operations and data handling. The telescope allocation process was also discussed as well as several related topics.

Working groups within the SWG used a standard template to capture the hypothetical observing programs in 2008. The template was modeled as a typical scientific observing proposal, followed by additional information that would more likely be gathered in a planning phase for the experiment. The goal was to provide a common outline on which to describe a range of use cases while guiding the community

through various considerations for future observing programs. These use cases were used to further develop the OCD.

A detailed discussion was focused on operational modes for the ATST. Current solar telescopes such as the Dunn Solar Telescope are operated in the classical mode. In order to maximize the scientific output of ATST, the SWG advocates strongly for implementing solar adaptations of queue and/or service modes, with the classical mode becoming the exception. The implications of this recommendation for the ATST operations plan as well as operational concepts will be assessed.

Recognizing the depth of expertise available in the international astrophysics community, the SWG recommended that the ATST project management contact European and other international partners regarding the possibility of cooperating in areas such as detectors and large-diameter etalons and coatings for the Visible Tunable Filter (VTF) Fabry-Perot filter system.

5.1.2 ATST Project Organization

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

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

- **High Altitude Observatory** (Visible Light Spectro-Polarimeter Design; Near IR Spectro-Polarimeter Contributions).
- University of Hawai'i (Sky Brightness Monitor and Dust Monitor; Diffraction- Limited Near-Infrared Spectro-Polarimeter and Cryo Near-Infrared Spectro-Polarimeter Design (Lead); Site Survey Operations on Haleakalā and Mauna Kea).
- University of Chicago (Site Survey Project Engineer; Theoretical Support for Science Working Group).
- New Jersey Institute of Technology (Site Survey Operations at Big Bear; Tunable IR Filter Design).

In addition, an international advisory group, chaired by Jeff Kuhn (U. Hawai'i), was formed, comprising representatives from several countries including the U.S., Germany, France, Italy, Spain, the United Kingdom, Netherlands, Sweden, Japan, and Norway.

5.1.3 Construction Phase Proposal Review

Since the successful NSF-conducted Preliminary Design Review (PDR) in October 2006, the project has held various area-specific design reviews. The project moved from "readiness" stage to the final stage of Major Research Equipment and Facilities Construction (MREFC) review at the August 2007 National Science Board meeting, where it was "RESOLVED, that the National Science Board authorizes the [NSF] Director at his discretion to include the construction of the Advanced Technology Solar Telescope in a future budget." The project held final System Design Reviews (SDRs) for the Support and Operations buildings, Telescope Mount Assembly and Enclosure on November 4-6, 2008. On May 18-21, 2009, the NSF conducted the Final Design Review, which resulted in the recommendation that ATST is ready to proceed into construction.

5.1.4 Proposed Site and Permitting

5.1.4.1 Site Selection

The ATST site survey, which started operating in November 2001, was successfully concluded in January 2005. Six sites were evaluated: 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.

In particular, the scintillometer array produces data that can be inverted to provide a reliable estimate of the structure function, Cn2(h) and thus obtain values of r_0 (the Fried parameter) at heights of up to 50 m above the ground. The value of r_0 at the height of the telescope aperture was the deciding factor in the site selection. The Site Survey Working Group (SSWG) delivered its final report in August 2004. The report was evaluated by the Science Working Group, which issued its site recommendation for Haleakalā to the project director in October 2004. Taking into account cost and feasibility issues summarized by project management, the ATST director accepted the SWG's recommendation for Haleakalā as the proposed ATST site.

Haleakalā was selected due to:

- High quantities of excellent seeing ($r_0 > 12$ cm) at the height of the main mirror (28 m).
- Very dark sky with little seasonal variation.
- Low dust counts and benign environment (e.g., outside temperature).

The final report of the SSWG is available at *http://atst.nso.edu/site/reports_final.html*. The overall ATST design approach and impact of the selection of Haleakalā on the overall design has been reported previously.

5.1.4.2 Site Permitting

Environmental permitting for ATST at the selected Haleakalā site requires the preparation of a full Environmental Impact Statement (EIS) as defined by Federal and Hawaiian statutes. In 2005, the Mauibased firm of KC Environmental (KCE) was contracted to lead that effort. Following the published Notice of Intent, a series of scoping meetings were held on Maui to elicit early input from the public on the issues to be addressed in the EIS. As reported previously, the main concerns include: the visibility of ATST from below, due to its required height and white color; the potential impact of ATST on native wildlife, particularly the endangered Hawaiian petrel; and increased traffic on the observatory road during construction and operation. Comments from the public and concerned agencies were taken into account in the preparation of the draft EIS (DEIS), which was released in the fall of 2006.

Following release of the DEIS, meetings were again held on Maui to allow the community to verbally respond to the document. During the prescribed review period, written responses were also accepted from the public, community groups and agencies. The input received largely reinforced the concerns that previously had been identified. In particular, the adjacent Haleakalā National Park raised concerns about the construction-related use of the 11-mile section of highway that runs through, and is maintained by, the Park. They cited potential negative impact on Park visitor experience caused by the increased traffic and also by the visual presence of another nearby large observatory. The Park's response pointed out the historic nature of the Haleakalā highway itself and the potential for damage caused by construction

traffic. The Federal Aviation Administration, which operates a repeater station on Haleakalā for air-toground communications, expressed concern about signal reduction caused by the proximity of the ATST structure to their antenna. Mutually acceptable measures to address these issues are being discussed in direct contact with the concerned agencies. With regard to the endangered-species issue, the U.S. Fish and Wildlife Service (USF&WS) completed a Biological Opinion on the impact of ATST. In consultation with KCE and project engineers, a set of reasonable mitigation measures were established which resulted in a USF&WS opinion that the ATST project is "not likely to adversely affect the Hawaiian petrel" or other species of concern. This finding was a significant positive development for the ATST EIS.

Environmental permitting also involves satisfying the applicable provisions of the National Historic Preservation Act (NHPA). Section 106 of the NHPA provides the legal framework for addressing such issues as the Park's concern about the historic highway and the Native-Hawaiian community's concerns about the sacred nature of the Haleakalā summit. In conformance with NHPA, a number of meetings with the public and concerned agencies have been held; proposals for mitigation and minimization of cultural impact have been invited and received. Meetings were held in June and August (2008) to begin to finalize a Programmatic Agreement with the community and agencies. The final Programmatic Agreement document was released in September 2009.

As the Lead Agency for the Proposed Action, the National Science Foundation is directing that process, and significant progress has been made. The Final EIS (FEIS) was competed in July 2009, and a Record of Decision (ROD) is expected to follow in the fall of 2009. With the release of an ROD, assuming approval of the project for construction, the project will proceed with the application for a Conservation District Use Permit, as required by Hawaiian statute. The University of Hawai'i will lead the state permitting process.

5.1.5 Project Progress

Design activities during the past year were focused on completing follow-up activities based on committee recommendations from the Systems Design Reviews held in 2008 and the Final Design Review 2009. Work has also been focused on completing bid packages in preparation for a possible 2010 start. To that end, work on the Reference Design Studies and Analyses (RDSA), interface control document (ICD), and bid package documents continues to proceed.

5.1.5.1 Support Facilities

The basic layout and design of the support and operations (S&O) building was completed this past year. Schematic drawings that detailed the site, building, pier, and lower enclosure designs were finalized and used as the basis of an architecture & engineering (A&E) request for proposal (RFP). Also included in this RFP were a design requirements document (DRD), Statement of Work (SOW), and a number of Interface Control Documents (ICDs) and other requirements documents. These documents, along with cost, schedule, and risk analyses were presented at a SDR in November of 2008, and then again at the FDR in May of 2009.

A request for pre-qualifications was advertised for the design completion work, with four A&E firms responding. All four were "pre-qualified" by the ATST project, with each then receiving the RFP package. Three of the firms submitted proposals. A source selection board met and scored the packages on the merits of their proposed technical, management, quality, and safety plans. Costs were then factored into the selection. The result was a recommendation to the ATST Project Manager that M3 Engineering of Tucson, Arizona, be selected for producing the construction drawings of the S&O buildings, pier, lower enclosure, and site development work. Contract negotiations were then held with M3, and a signed contract by M3 sent to AURA for approval. Work is tentatively planned to begin in late October of this year, pending approval by AURA.

5.1.5.2 Optical Design

The ATST is an off-axis all-reflecting Gregorian telescope. The off-axis design gives the best stray-light performance, which is critical for coronal observations. The all-reflecting characteristic is the only solution that potentially can allow observations at wavelengths from 300 nm to 12 μ m with enough flexibility to use some instruments simultaneously.

The Gregorian optical design forms a prime-focus image in front of an ellipsoidal secondary. This focus is only used as a field stop, limiting the telescope field of view to five arc minutes; the rest of the beam is rejected. This reduces the 12 kilowatts of power reflected from the primary to about 300 watts or less on all subsequent optical elements. The secondary mirror then relays the prime focus image to an f/13 Gregorian focal plane. The Gregorian focus, which will be used for calibration and polarization optics during normal operations. The beam is then nearly collimated and relayed to the coudé observing station.

During 2009, the project made no changes to the optical design outside of the coudé lab but has made significant simplification of the design within the coudé lab. This work was due to an increased priority for simultaneous instrument operation at first light. Based on this simplified design, the project has begun to explore details of the interface between instruments, wavefront corrections system and the telescope. The concept of splitting the available light between instruments has been developed and is being evaluated.

5.1.5.3 Telescope Mount Assembly

Progress this year on the telescope mount assembly (TMA) has focused primarily on drafting the Request for Proposal (RFP) package and preparing for contracting. The documents that comprise the RFP include the Statement of Work (SOW), Specification Document, numerous Interface Control Documents (ICDs), and a variety of supporting requirements documents, such as QA/QC, Safety, and site restrictions. In addition, the CAD model of the TMA was updated and a second revision to the Reference Design Studies document prepared. Also, a draft Source Selection Plan (SSP) was generated. Informal discussions with a number of potential TMA contractors were also carried out, and, in one instance, included a funded cost study. Finally, a series of Hazard Analyses were performed on the TMA reference design, which helped refine specifications and interfaces to other subsystems.

The TMA design, specifications, cost and schedule estimates, and risk analyses were presented at a Systems Design Review in November 2008, then again at the NSF-conducted Final Design Review in May of 2009. Key staff have been recruited and hired to oversee the TMA contract package, and final vetting of the documents by the ATST Contracts Officer have begun.

5.1.5.4 Enclosure

Like the TMA, the work on the Enclosure this past year has focused on finalizing contracting strategies and preparing the RFP packages. Unlike the TMA, however, the Enclosure work has been separated into three smaller sub-contracts that will each be competitively bid. These are a) the enclosure itself; b) the enclosure thermal systems; and c) the enclosure control systems. This approach was taken to maximize the number of potential bidders for the work, and therefore maximize the competitiveness of the procurement process. The support SOWs, Specification and Design Requirements Documents, ICDs, and source selection plans have been reviewed and updated. These documents, along with CAD reference designs, cost and schedule estimates, and risk analyses were presented at both an SDR in November 2008, and at the FDR in May 2009. Key staff have been recruited to oversee the enclosure contract packages, and final vetting of the documents by the ATST Contracts Officer have begun.

5.1.5.5 Wavefront Correction (WFC)

The ATST wavefront correction system must achieve the high Strehl requirements at visible and infrared wavelengths called for in the Science Requirements Document. The ATST has several correctors and sensors for wavefront correction, including: 1) quasi-static alignment (QSA) for keeping the entire optical path—most importantly M1 and M2—aligned in closed-loop; 2) active optics (aO), which has the main function of keeping the figure of M1 within specifications, compensating for deformation due to gravitational and thermal distortions; 3) tip/tilt devices for image stabilization; and 4) high-order adaptive optics (HOAO) for correcting atmospheric and internal seeing and residual optical aberrations.

The subsystems of the ATST wavefront correction system include:

- A high-order adaptive optics system. This sub-system corrects atmospheric seeing at >2 kHz rates. The baseline design has a 1369-actuator deformable mirror (DM) and a fast tip/tilt mirror. The wavefront sensor is a correlating Shack Hartmann sensor with 1280 subapertures. The approach builds on the very successful AO systems deployed at the Dunn Solar Telescope. This system also includes a fast tip/tilt mirror (M5).
- *Active optics system.* The main task is to correct slowly changing aberrations that may arise from gravitational and thermal deformations of the telescope structure. One of the main objectives of the system is to keep the figure of the primary mirror within the allowed tolerances.
- *Alignment*. The ATST's off-axis optical system alignment requires wavefront measurements at several points within the extended field of view. This multiple field wavefront sensor will be available at the coudé station.
- *Blending*. Information from different wavefront sensors (e.g., AO and Ao) will be conditioned and combined by the Wavefront Correction Control System (WCCS), which then drives the appropriate corrector elements.

Each of the wavefront sensors has a computer that processes the wavefront information in real time and outputs information to one or more correctors. This is done either directly, where high bandwidth is required (e.g., DM), or through the WCCS. The WCCS is a system with supervisory role that coordinates all of the wavefront correction systems. It will control which sensing system will control which corrector. It accepts commands from the Telescope Control System (TCS) and passes them on to the appropriate system. The main task of the WCCS is to blend information from the operating wavefront correction systems for M1 figure and adjustments to the telescope optics for alignment. For instance, when both the Ao and HOAO systems are running at coudé, the Ao system is measuring the wavefront at the center and two corners of the field. However, the HOAO is correcting the center of the field and hence the HOAO will off-load quasi-static aberrations from the center of the field to the WCCS.

Based on recommendations from the WFC FDR committee, the project is actively engaged in a modeling and prototyping effort with a DM vendor to mitigate risk. If the modeling results indicate that the proposed approach of a "thermally managed" DM is a viable option for the ATST DM, we will proceed to implement this approach into the prototype device. The project will later purchase the WFS camera and contract the necessary camera-to-DSP interface development as funds become available. The camera will be evaluated in-house. In parallel, we will continue to explore potential secondary sources for this critical component.

5.1.5.6 Software

The Observatory Control System (OCS) and Data Handling System (DHS) designs were extensively reworked to address input from the science community. The designs now contain science requirements flow-down, use cases and user interface prototypes, and additional examples of programming details. The Instrument Control System (ICS) is now into the preliminary design stage as the specific requirements of the instruments emerge from the various instrument programs. The ICS now supports multiple simultaneous instrument operations and detailed sequencing and control of instrument mechanisms. In September 2009, the design progress of these three systems and the associated Operational Concepts Definition document (OCD) were presented to the Science Working Group and the ATST scientists.

The Common Services Framework (CSF) software infrastructure has been tested and used in several telescope and mechanism simulators. A contract to complete the C++ port of CSF has been let to Observatory Sciences, Ltd., and is expected to be completed in March 2010. The CSF beta release will occur shortly thereafter.

Work on the telescope subsystems has progressed into the system design area in preparation for contract releases. All design and documentation work on the telescope enclosure control system and mount control system has been completed, including the reference design, specifications, and interfaces. The mount and enclosure control systems have passed a systems design review.

5.1.6 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 EIS process, and review of the construction proposal will be the principal project planning activities. Near-term design efforts are concentrating on refinement of the thermal control design for the enclosure, detailed optical feeds to instruments, more complete instrument concepts, system-error budgeting, and performance modeling using the latest Haleakalā site data. Risk management analysis continues and is being fed back into the project budgets (e.g., contingency), schedules (e.g., schedule contingency) and planning (e.g., in-process spares, integration, testing, and commissioning (IT&C) planning and staffing). Responses and actions resulting from the FDR will be planned and executed.



Figure 5.1-1. Renderings of the ATST at the proposed primary (left) and alternate (right) sites on Haleakalā.

5.1.6.1 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 have begun for transitioning to operations that will enable life cycle planning during the design process and help prepare the National Solar Observatory for the operational phase of ATST.

5.1.6.2 Construction Phase

Current planning, based on an FY 2010 construction start, has calendar year 2017 targeted for obtaining the first scientific data with an ATST instrument. 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.

5.1.6.3 Funding

In FY 2010, 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 as soon as the Cooperative Supplement Agreement is established (end of December 2009). This is anticipated to occur in at the beginning of FY 2010. 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, the Preliminary Design Review Committee in October 2006, and the Final Design Review Committee in May 2009.

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) Major Research Equipment Facilities Construction (MREFC) requirements; and (6) commodity cost increases.

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

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

The estimate of required funds is shown in Figure 5.1-2, assuming no advanced purchase of the primary mirror. Inflation and an overall 25% contingency on base costs are included.

Figure 5.1-2 also shows the time-phased funding profile for construction.

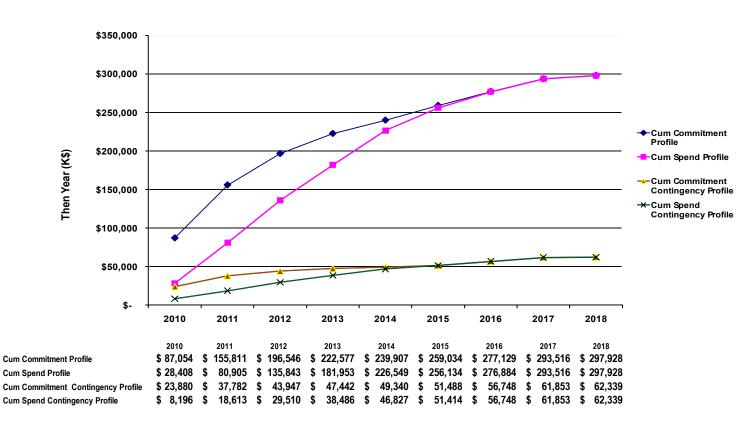


Figure 5.1-2 ATST Cumulative Commit vs. Spend Profiles (Includes Contingency).

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

To maintain the project team, support the on-going EIS process, and perform recommended risk mitigation studies with industry, NSO requested additional funding to the projected ATST FY 2009 budget. NSF provided an addition \$1.4M raising the total available in FY 2009 \$3.2M. The American Recovery and Reinvestment Act is providing an additional \$3.1M. The \$3.1M has been used to support the project team through the final phases of the D&D effort, for EIS support, to begin architectural and engineering efforts, design feasibility and analysis studies with industry, to order a deformable mirror for the wave front correction system, and to support software efforts.

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

5.2 SOLIS Global Network

NSO is now seeking international (or other national) partners and, if successful, proposes to build two additional SOLIS Vector Spectromagnetograph (VSM) units in response to the desired capability outlined in the NAS/NRC decadal survey, "Astronomy and Astrophysics in the New Millennium." These units will be placed at distant longitudes and operated to form a SOLIS network capable of much more complete coverage of transient solar activity.

The establishment of a three-site SOLIS VSM global network will enable synoptic, full-disk observations of the Sun on a nearly continuous 24/7 basis. This capability, in turn, will provide a powerful complement to current and forthcoming solar space missions. A VSM network will further provide simultaneous, or near-simultaneous, contextual data in coordination with other international ground-based solar telescope facilities such as the ATST, GREGOR, the Swedish Vacuum Telescope, and others throughout the world. The full-disk vector capabilities and high sensitivity are an excellent complement to the high-cadence longitudinal magnetograms produced by the GONG network.

The core synoptic program for the single VSM is three full-disk vector magnetograms per observing day at roughly three hours apart. That cadence was set by the amount of time anticipated to do full inversions of full-disk vector magnetograms. Faster would be better from a science perspective. It takes about 20 minutes to make a full-disk vector observation, but that can be increased or decreased depending on the desired signal-to-noise ratio. A single active region can be observed every two minutes with good results by restricting the scan size. A SOLIS movie of the vector field at disk-center (prepared by C. Keller) reveals network fields changing on a time scale of minutes, presumably due to buffeting by granulation. Two additional sets of three full-disk vector magnetograms per site per day have the value of tripling the chance of observing transient activity such as flares and CMEs, and more rapid detection of their observational precursors. The identification and investigation of flare and CME precursors are essential for accurate space-weather forecasting. Catching a major flare in a fast sequence of good vector magnetograms would answer many long-standing questions.

A VSM network will enable the study of magnetic field changes associated with transient activity such as flares and coronal mass ejections, in addition to documenting the long-term changes associated with the solar cycle. Furthermore, a three-site global VSM network will:

- have three times better chance of capturing rare events;
- produce improved potential for short-term activity forecasts;
- have the ability to detect and correct systematic data errors;
- be more robust against a single-site failure;
- provide improved constraints on theoretical models of activity;
- generate opportunities for international scientific collaboration; and
- stimulate stronger research programs on solar activity.

5.2.1 Structure of a SOLIS VSM Network

The basic structure envisioned consists of three VSM instruments distributed around the world at sites with longitudes that include the southwestern U.S., Europe/Africa (+8 hours) and western Australia/Asia (-8 hours). It should be noted, parenthetically, that the ATST site on Haleakalāā is at a less favorable longitude for a three-site global network than candidate sites in the southwestern U.S., such as Big Bear Solar Observatory or the present site at Kitt Peak. The other desirable site characteristics include clear skies at least 60% of the time and good seeing during the course of a day.

The NSF Senior Review recommended that a SOLIS network be formed through funding contributions by international partners. The partners could build clones themselves or contract the NSO to construct replicas of the VSM. NSO's estimate of the cost to replicate the SOLIS VSM is approximately \$5.5M (full-cost accounting with an estimated 20% error) in FY07 dollars. The VSM currently in operation on Kitt Peak will require some redesign in order to (1) update various electronic components, and (2) increase the ease of maintenance. Of course, building two identical VSM instruments in parallel would reduce the unit cost for each.

The NSO has found potential partners in Germany, Spain and Australia. Together with these potential partners, a proposal was submitted to NSF/ATM. While receiving excellent reviews, the proposal was not funded. NSO will continue to seek funding opportunities for a SOLIS network.

5.3 Virtual Solar Observatory (VSO)

In order to leverage further the substantial national investment in solar physics, NSO is participating in the development of the Virtual Solar Observatory and the Collaborative Sun-Earth Connection (CoSEC). The VSO comprises a collaborative distributed solar-data archive and analysis system with access through the WWW. Version 1.0 of the system was released for general public use in December 2004, and Version 1.2.4 was released in December 2008. Usage by the solar community is growing rapidly, with 600,000 files totaling 25 TB distributed during the period July 1, 2008, through March 31, 2009. The overarching goal of the VSO is to facilitate correlative solar physics studies using disparate and distributed data sets. Necessary related objectives are to improve the state of data archiving in the solar physics community; to develop systems, both technical and managerial; to adaptively include existing data sets, thereby providing a simple and easy path for the addition of new sets; and eventually to provide analysis tools to facilitate data mining and content-based data searches. None of this is possible without community support and participation. Thus, the solar physics community is actively involved in the planning and management of the Virtual Solar Observatory. None of the VSO funding comes from NSO; it is fully supported by NASA. For further information, see *vso.nso.edu/*.

In the time frame covered by the current cooperative agreement, NSO should continue to be a central component of the VSO. In addition, the NSO archives should be observatory-wide with components at both sites. These components should link enhanced pipeline processing systems similar to those now available, such as ISOON and GONG++, massive storage systems based on the initial SOLIS system, an instrumentdriven pipeline and PI data-capture systems at all NSO observing facilities, and a large-scale photographic digitization system. The details for this expansion have been discussed in the NSO Data Plan (see *www.nso.edu/general/docs/*). At this time, the GONG and SOLIS data processing systems are being merged as a a major step towards the establishment of the NSO Synoptic Program.

The ATST Data Handling System (DHS) included in the construction proposal provides a common data transfer and storage service for all ATST facility instruments. The DHS supports four areas of instrument data requirements: transfer, storage, display for quality assurance, and retrieval. Data handling begins with the high-speed transfer of large data sets from one or more instruments. The data are organized and stored according to observation type and originating instrument, then integrated with observatory data such as experiment, investigator, and telescope status. Each observing program will have a unique identifier. Users requiring a real-time display of the data can request a quick-look display. The data set created by an experiment will be move to temporary storage and then sent to the NSO data processing and archiving facilities for further reduction and dissemination.

Data that have been collected and temporarily stored at the summit will be transferred to processing facilities at the ATST Support Facility on Maui and to NSO Headquarters. The exact amount of storage and processing power to locate on Maui will be determined during construction and will depend on several factors, including data transfer costs, hardware costs, and personnel costs. Any extensive processing would occur at a data center located at NSO HQ that also supports other NSO programs. The ATST Support Facility on Maui, should at a minimum have sufficient capability to allow ATST staff stationed on Maui to reduce some of the data to further insure quality and that the objectives of the observing run are being met as well as to conduct their own research.

An ATST data archive is not considered to be part of the baseline ATST construction. Science and engineering data produced by ATST will have a high enough value that they should be archived either permanently or for extended periods as determined by the NSO data policy for ATST. There will need to

be a selection process to eliminate marginal data. Some (small) fraction of this can occur at the telescope before downloading off the mountain, but most will require at least some level of processing to determine the quality of the data. Ideally we will store all (good) raw data along with their calibrations. Data that are reduced by NSO for community access would be stored for defined periods of time that take into account their usefulness as judged by downloads from the community. ATST data will become part of the NSO digital library and will share resources with other NSO programs. NSO can exploit the large amount of data center expertise that already exists within the NSO GONG and SOLIS programs. Data will be made available via FTP, the WEB, and through the Virtual Solar Observatory.

As we transition to ATST construction, NSO plans to hire a data center scientist who will devote full time to the architecture and software needed to process and archive ATST data. He or she will work closely with the GONG and SOLIS data teams to ensure consistency within NSO. We plan to fully exploit tools that have been developed for the Solar Dynamics Observatory and other space missions as well as explore commercial venues (e.g., Google) for data retrieval and storage.

6 EDUCATION AND PUBLIC OUTREACH AND BROADENING PARTICIPATION

NSO conducts a vigorous public affairs and educational outreach program that includes graduate research and training, undergraduate research, teacher research and research-to-classroom experiences, public programs, media information, elements of distance (Internet) learning, and K-12 education. NSO has also embarked on a program to broaden participation in its outreach and staffing, as well as in science in general. Part of our initial aims is to increase awareness of the need for solar physics research and the potential for careers in the field among African American, Hispanic, Native American and Native Hawaiian populations, as well as provide to levels K-12 general scientific material based on skills needed to understand aspects of our nearest star to help seed the path to higher education and jobs. This will include expanded outreach through established education and professional venues and direct contacts with minority-serving schools. As NSO moves into the ATST era, it plans to expand its outreach programs in several of the STEM areas through proposals and partnerships, including the establishment of effective outreach in Hawai'i by partnering with groups already involved in Hawaiian outreach programs. Section 6.2 presents a draft program that will be the subject of a proposal to NSF for some of the actions NSO plans to initiate as ATST is developed and into the era of ATST operations on Maui.

The primary NSO EPO objectives and goals are:

- To help train the next generation of scientists and engineers through support for undergraduate and graduate students, and postdoctoral fellows, and close collaboration with universities and the ATST consortium.
 - Continue our successful REU program.
 - o Strengthen our Summer Research Assistantship for graduates program.
 - o Increase the number of thesis students working at NSO.
- To develop K-12 teacher training and student training programs to advance knowledge of science and technology.
 - o Strengthen our Research Experience for Teachers (RET) program.
 - o Make RET lesson plans available on the WWW.
 - o Develop solar classroom material that illustrates general math and physics.
- 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.
 - o Increase the relevance and content of our WWW outreach.
 - o Develop outreach materials for both classroom and public distribution.
 - o Complete our solar system model and the handout materials that accompany it.
- To increase nationally the strength and breadth of the university community pursuing solar physics.
 - Work closely with our ATST university partners and other groups to recruit and help diversify the community of scientist doing solar research.
 - Establish close ties with additional universities to provide NSO thesis students.
- To enhance the understanding and application of science and math education in our schools, colleges and the public at large, and among traditionally underrepresented communities (Hispanic, Native American, African American, and women).

- Create models, display, and support packages for teachers using solar physics as examples of physical phenomena.
- o Create ties with schools and universities serving underrepresented minority groups.

Current NSO EPO resources include the ~1.3 FTEs of scientific staff time (~\$150K) shown in Table 3.1, \$132K from NSF to support the REU/RET programs, one full-time EPO staffer (~\$90K), \$50K support for a Visitors Center and tours, and part-time support from members of the administrative and technical staff totaling approximately 0.5 FTEs (\$55K). In addition, NSO transfers \$108K to NOAO to participate in their EPO programs. Thus the total resources going into EPO are approximately \$580K. NSO has generally asked one scientist at each of its sites to shepherd its REU and RET programs. Other outreach is conducted as time permits using time from both science and support staff members. With the advent of the ATST D&D proposal, NSO hired an ATST PR-Outreach officer, who has integrated his efforts with the rest of NSO. NSO also provides funding to the NOAO Public Affairs and Educational Outreach (PAEO) group and participates in several of their programs. The programs described below are conducted with time from both science and support staff from the observatories. In spite of these limitations, NSO has maintained an active outreach program with a great deal of success, especially in the area of bringing new personnel into solar physics.

6.1 Recruiting a New Generation

The future of solar physics hinges on the successful recruitment of a talented new generation of scientists by the universities and national research organizations.

6.1.1 Existing Higher Education Program

Since its formation as a national observatory in 1983, NSO has actively participated in the recruitment of new generations by conducting annual programs that offer undergraduate, graduate students, and middleand high-school teachers opportunities to participate in astronomical research (see Table 6.1-1).

Opportunities are provide at our Sunspot, New Mexico and our Tucson, Arizona sites. Six to eight undergraduate students work closely with NSO staff each year through the NSF Research Experience for Undergraduates (REU) program for ten to twelve weeks in the summer. During summer 2009, participants in the NSO program included three females (one Hispanic) and three males (one Hispanic).

The NSO summer research assistantship (SRA) program provides opportunities for graduate students and additional opportunities for undergraduates to work at NSO. This program has been extremely effective in attracting graduate students into the field of solar physics with over 50% of the graduates going on to postdoctoral fellowships in solar research and over 80% staying in astronomy. Many of the current NSO staff and the science staff at other institutions have participated in this program.

Tabl	Table 6.1-1. Number of Participants in NSO Educational Outreach Programs (2003–2009)								
Year	Graduate (SRA)	Undergrad (SRA)	Undergrad (REU)	Teachers (RET)	Postdoctoral Fellows				
2009	6*		6	2	6				
2008	7*	1	6	0	6				
2007	9*		6	4	7				
2006	4		7	4	5				
2005	9		8	4	5				
2004	6	1	6	4	3				
2003	7		8	3	4				

*Includes students participating in 10-week IRES summer program (see Sec. 6.1.3).

6.1.2 Increasing the Diversity of NSO's Student Programs

Diversity of the solar physics workforce is a topic that deserves special attention. Diversity can only be ensured if the solar physics community fosters students in the early career stages. Middle and high schools experience a high attrition rate of underrepresented minorities and women concentrating their studies in math and sciences. NSO is working towards diversifying the pool of college students studying astronomy and physics. This task is complex and must occur at all stages of apprenticeship: postdoctoral, graduate, undergraduate, and early education (high, middle and elementary school).

In an effort to attract students from underrepresented areas into summer research internships, our mailing list includes colleges from the Historically Black College List generated by the NSF and a list of American Indian Science and Engineering Society affiliates. As can be seen in Table 6.1-1, racial minority enrollment in NSO REU programs has been small, and it is our goal to increase these numbers by participating in more directed recruitment and involvement in the Partnerships in Astronomy & Astrophysics Research and Education (PAARE) program. NSO and ATST staff have begun exhibiting and recruiting at several venues designed to attract a broad range of students and teachers. NSO activities in FY 2009 included (chronologically):

- Exhibit at New Mexico Science Teachers Association convention, Albuquerque (Oct. 2008).
- Exhibit at regional meeting of National Society of Black Physicists, El Paso (Oct. 2008).
- Exhibit at Space Explorers Education Days, New Mexico Museum of Space History, Alamogordo (Oct. 2008).
- Participation in New Mexico Association of Museums conference, Roswell (Nov. 2008).
- Presentation of invited talk at the Texas Astronomical Society, Dallas.
- Participation in National Society of Black Physicists & National Society of Hispanic Physicists convention, Nashville (Feb. 2009).
- Presentation at the University of Arizona Native American Student Association (NASA) (Jan. 2009).
- Participation in Hispanics in Education conference at New Mexico State University, Las Cruces (Mar. 2009).
- Participation in Science for Latinos conference, Albuquerque (Mar. 2009).
- Presentation and exhibit at the "Region 3" meeting of the American Indian Science and Engineering Society (AISES) at Northern Arizona University (Apr. 2009).
- Exhibit at Spaceport America demonstration launch, Upham, NM (Apr. 2009).
- Participation in Working with Teachers and School children workshop hosted by Museum Development Associates, Las Cruces (Jun. 2009).
- Participation in Center for Astronomy Education workshop, Maui, Hawai'i (Jul. 2009).
- Participation in the Annual Teachers Open House at New Mexico Museum of Natural History (return request) resulted in several requests to bring Solar System display and materials into class rooms around the state. This has the potential of reaching a broad Hispanic audience. (Sept. 2009).
- Exhibit at New Mexico Science Teachers Association convention, Ruidoso, NM (Oct. 2009).
- Exhibit at the annual meeting of the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), Dallas (Oct. 2009).
- Exhibit at American Indian Science and Engineering Society (AISES) convention, Portland, including a presentation on the Sunspot Solar System model (Oct. 2009).

NSO has established formal partnerships with two institutions that have successfully applied for the NSF PAARE program. As described by the NSF synopsis, "the objective of PAARE is to enhance diversity in astronomy and astrophysics research and education by stimulating the development of formal, long-term, collaborative research and education partnerships between minority-serving colleges and universities and the NSF Astronomical Sciences Division (AST)-supported facilities, projects or faculty members at research institutions including private observatories." This is an exciting opportunity for NSO scientists to mentor students from Vanderbilt and Fisk Universities and New Mexico State University (NMSU). In

summer 2009, a graduate student from the Fisk-Vanderbilt Masters-to-PhD Bridge Program started a summer research internship at NSO/Tucson and is now working on a Master's thesis on flare excitation of high- ℓp -modes based on archived GONG data.

NSO has been successful with the inclusion of women in its program as more than half of the research undergraduates in recent years are female (see Table 6.1-2 for the gender and underrepresented minority breakdown of REU statistics for the past five years). Enrollment of women in graduate science programs has risen dramatically in the last decade, in part due to programs that foster girls' confidence in their scientific and mathematical abilities (see for example *http://www.aps.org/programs/women/workshops/-gender-equity/upload/genderequity.pdf*). In an isolated example of such a program, NSO recently participated in the development of a publication to be used as supplementary middle school education material to encourage more young women to pursue science careers (see Sally Ride Science, *www.SallyRideScience.com*, "The Inside Story of the Sun," 2007).

TABLE 6.1-2. NSO REU Participant Statistics (2005 - 2009)							
Year	2009	2008	2007	2006	2005	% Participants	
Male	3	4	2	1	5	45	
Female	3	2	4	6	3	55	
Minority*	2	0	1	0	0	9	

* Includes only students from underrepresented minorities (Hispanic and African-American).

6.1.3 Summer Schools

In 2006, 2007, 2008, and 2009, NSO partnered with the Lunar and Planetary Laboratory at the University of Arizona to present a Solar Physics Summer School. The summer school consists of undergraduate and graduate students attending a week-long program featuring lectures on the most exciting contemporary solar physics research. These summer schools have been held at NSO Sunspot with approximately 35–50 attendees from all over the world. Lectures at the summer school include some NSO and University of Arizona staff, but most come from outside organizations. The grant to the University of Arizona that paid for the program ended this past year. NSO plans to seek new funding to continue this highly successful school. NSO also continued its participation in the International Research Experience for (Graduate) Students, or IRES. The program has taken place in Bangalore, India in the summers of 2007, 2008, and 2009 under the auspices of the Indian Institute of Astrophysics. The program has been renewed and will continue for an additional three years with strong NSO participation.

6.1.4 Interactions with the University Community

The recent NSF program that has resulted in four new solar physics faculty at four different universities will greatly aid and ensure the health of solar physics in the U.S. The positions, partially funded by NSF, were awarded to the Institute for Astronomy (IfA) at the University of Hawai'i, the Lunar and Planetary Laboratory (LPL) at the University of Arizona, the University of Colorado, and most recently, New Mexico State University. As a result of this NSF initiative, three PhD students are working on thesis projects in close collaboration with NSO. In 2007, the strengthened solar physics group at LPL successfully recruited a solar physics graduate student who participated as an REU with NSO and is now working closely with scientists at NSO on his thesis. These new positions have helped foster closer ties between NSO and the university community.

Additional interactions with U.S. universities that involve graduate students include: A graduate student at NMSU who has started work on his PhD with NMSU, Air Force, and NSO support. A University of Hawai'i student is working on her thesis based on a University of Hawai'i instrument located at NSO. All three of these thesis students previously participated in NSO REU or SRA programs.

Most recently, NSO has collaborated with minority serving universities such as the California State University at Northridge and New Mexico State University in the formulation of MRI-R² proposals to enhance their research and educational programs.

6.1.5 Mentoring of Postdoctoral Fellows and Thesis Students

Most NSO postdoctoral fellows come to the observatory on grants held by individual NSO scientists, not on the NSO base budget. One major exception has been the ATST program, which has hosted regular ATST fellowships. All postdocs have a scientific staff mentor who consults on and guides their work. The mentor provides supervision as well as research guidance on a regular basis. Since many of the postdocs at NSO are directly involved in observations, the mentor also provides training on instrumentation and observing methods. The mentors as well as senior NSO management staff also provide professional guidance that includes discussions about and reinforcement of principles of scientific research ethics.

In addition to the assigned mentor, NSO postdoctoral fellows and thesis students interact with other members of the scientific staff, often forming collaborations that provide the benefit of a broader range of experiences. We hold regular staff seminars and informal science exchanges to further broaden exposure to all aspects of solar physics. Visiting scientists regularly give seminars and interact with the NSO staff and postdocs, providing the opportunity to make connections throughout the solar community. At NSO/Tucson, co-located with the NOAO on the University of Arizona campus, NSO postdocs are exposed to the entire range of contemporary research in astrophysics through seminars and colloquia in this active segment of the astronomy community. The NSO and the University of Arizona Lunar and Planetary Lab jointly sponsor a "brown bag lunch" seminar series on topics primarily in solar and heliospheric physics in which all the scientific staff, including postdocs, participate as speakers on a regular basis. In addition, NSO encourages and provides resources for our postdoctoral fellows to attend and present their research at professional meetings.

We work closely with our postdocs on creating their resumé and in finding opportunities to enter the permanent solar workforce. This process has been very successful; almost all of our postdoctoral fellows doing solar research have found positions in solar physics or closely related fields. Several of the postdocs over the past 10 years have worked at NSO in instrumentation and have taken jobs in industry or in developing instruments in other fields.

Frequent contact is an important part of mentoring, particularly with postdoctoral fellows who have limited experience. The GONG program holds bi-weekly individual meetings between the program scientist and each scientific staff member, as well as a bi-weekly science roundtable which is attended by all of the GONG scientists. Individual meeting frequency is higher for postdocs, with a weekly cadence. In addition, new postdoctoral hires are provided with a reading list, and telecoms are held to discuss questions prior to the start of their employment.

NSO is working to establish a more formal career counseling program involving senior scientific staff, and will implement a program for tracking the career paths of our postdoctoral fellows. NSO scientists regularly prepare grant proposals for instrumentation and research support that provide the opportunity to train postdocs by including them in the proposal development and preparation. All of NSO's postdocs are encouraged to mentor undergraduate and graduate student participants in our annual Research Experiences for Undergraduates (REU) program and Summer Research Assistantship (SRA) program for

graduate students. They receive advice from their mentor as well as NSO scientific, management, and administrative staff on best practices gleaned from many years of conducting these programs. These programs involve students from many different backgrounds and locations throughout the U.S. and the world, providing postdocs with experience in dealing with diverse groups.

6.1.6 K-12

Programs for Science Teachers

NSO participates in the NSF-funded Research Experience for Teachers (RET) program, which offers middle and high school teachers an opportunity to apply physics, engineering, and mathematical methods to research problems with the understanding that these experiences will be incorporated in their classroom lessons. Participants in the RET program spend the summer either in Sunspot or Tucson. During the summer of 2009, two teachers participated, including a male African American mathematics teacher from Milford Mill Academy in Princess Anne, Maryland and a female LaRue County Middle School teacher from Hodgenville Kentucky.

In the past five years, NSO has participated in the Teacher Leaders in Research Based Science Education (TLRBSE) program developed by NOAO. This is an NSF-funded program that enhances middle and high school teachers' ability to teach science by providing them with a hands-on research experience for two weeks in the summer when they attend a workshop at NOAO Tucson. The RET and TLRBSE programs ultimately enrich the classroom experiences of K-12 students as their teachers have a hands-on knowledge of solar physics research problems and can convey their knowledge and enthusiasm from a personal point of view. NSO plans to continue its commitment to the RET program, but will not actively participate in the TLRBSE program in the future as this program will be paired more exclusively with NOAO scientific mentors. However, a solar physics option for study, and the use of the McMath-Pierce Solar Telescope, will remain included in the TLRBSE program.

K-12 Classroom Research Activities

Two educational modules were developed by NSO to be used in the classroom at middle- and high-school levels. The Researching Active Solar Longitudes (RASL) project is geared towards improving students' computer and analytical skills in addition to becoming familiar with fundamental solar science. The Data and Activities for Solar Learning (DASL) project provides classroom experience for middle or high school students to study the properties of the Sun's magnetic cycle. In addition to providing and collating the data, NSO provides assistance in using the modules. Those wishing to incorporate this data set and activities will find that it addresses many of the national science standards. Both Project 2061 and the National Science Education Standards are referenced to provide validity for performing such investigations in the classroom. This resource is rich in scientific content standards as well as emphasizing scientific process standards.

Project CLEA (Contemporary Laboratory Experiences in Astronomy) develops laboratory exercises that illustrate modern astronomical techniques using digital data and color images. They are suitable for high school and college classes at all levels, but come with defaults set for use in introductory astronomy classes for non-science majors. Each CLEA laboratory exercise includes a dedicated computer program, a student manual, and a technical guide for the instructor. NSO provides a module using GONG data that allows the student to measure solar rotation and learn about the difficulties of inferring three-dimensional information from two-dimensional projections.

Project ASTRO is a national program that improves the teaching of astronomy and physical science by linking professional and amateur astronomers with local educators. Each astronomer is matched with an educator in a one-on-one partnership and commits to visiting the educator's students at least four times

during the school year. NSO staff participate in the annual Project ASTRO two-day workshop hosted by NOAO and engage in mentoring throughout New Mexico and Arizona.

RASL, DASL, Project CLEA and Project ASTRO can all be accessed through the NSO education and public outreach link at *eo.nso.edu/*.

NSO is a strong participant in the Southwest Consortium of Observatories for Public Education (SCOPE). SCOPE is a consortium of research institutions in the Southwest that promotes public awareness of astronomy through access and education. This valuable collaboration results in excellent interaction among the public and educational outreach staff of these groups and includes cooperative promotion, visitor center display sharing, and the ability to leverage limited funding into additional outreach opportunities. NSO will produce materials that reflect the new capabilities of the ATST to describe solar astronomy and the effects of the Sun on the Earth for dissemination by SCOPE.

6.1.7 Public Outreach

Visitor Centers

The NSO Astronomy and Visitor Center at Sacramento Peak is host to over 15,000 visitors per year. A wide range of interactive education displays at the Visitor Center provide hands-on experience with astronomical and terrestrial phenomena, interactive demonstrations on the properties of light and how telescopes work, recent science results from both ground-based and space-based solar and astrophysical experiments, and access to interactive Web-based pages.

The Kitt Peak Visitor Center also attracts more than 40,000 public visitors annually. Exhibits adjacent to the gift shop include a large model of the McMath-Pierce telescope, a live feed for the solar image, and a hands-on display about spectroscopy and its solar science applications. Daily tours of the McMath-Pierce Solar Telescope are available. The McMath-Pierce Facility also includes an educational exhibit referred to as the "Sunnel." The tunnel that leads from the entrance to the Main Observing Room features exhibits or displays that take the visitor from the center of the Sun to its outer atmosphere along the length of the "Sunnel."

Because the Sunspot and Kitt Peak Visitor Centers are located in the Southwest, a large proportion of visitors are Hispanic and Native American. NSO provides tours in both Spanish and English.

During FY 2009, NSO completed design of major elements of the Sunspot Solar System Model and moved towards purchase and installation of the last elements by mid-FY 2010. Several designs are being adapted to be taken on the road to New Mexico schools and thus serve as a starting point for the Sun on Wheels, portable activities in ATST outreach. Podcast materials are being developed that will be available online. Designs and materials also were adjusted to allow translation into Spanish to help attract Hispanic audiences. NSO will also develop software to provide near-real time and other images to the National Air and Space Museum at NASM's invitation. These will be available to all museums.

Internet Resources and Public Web Pages

As the public becomes more Internet-savvy, organizations need to respond by continually updating their presence on the Web. The NSO Web site provides information to the public on solar physics and astronomy in general. A particularly successful interactive feature is the "Ask Mr. Sunspot" forum that provides a foundation for anyone on the Web to indulge in their scientific curiosity and ask specific questions. The Ask Mr. Sunspot feature is being revamped to streamline past answers into a comprehensive set and to write new tutorials about the Sun and ATST. NSO staff members respond to these questions individually.

Near-real-time solar images are also available from NSO instruments on the following Web pages *nsosp.nso.edu/data/latest_solar_images.html*, *solis.nso.edu/*, and *gong.nso.edu/*.

The Virtual Solar Observatory (VSO) is a cornerstone to ensuring that NSO data are accessible to all scientists internationally. Currently, data from GONG and SOLIS are routinely archived and available through the VSO portals.

6.1.8 *Future*

Even with the success of NSO's Education and Public Outreach, cultural changes demand that NSO grow with the times. NSO will continue to update and modernize its EPO programs. Some of the priorities will include:

- Increasing NSO's online presence in response to an ever-increasing use of the World Wide Web as a source of public information.
- Mentoring and advising more Ph.D. and post-doctoral students, especially U.S. nationals in areas directly relevant to ATST instrumentation calibration and science.
- Tailoring our student recruitment techniques to ensure diversity within the new generation of solar astronomers.
- Enhancing the content of our outreach modules and exhibits.
- Develop a proposal to expand NSO programs and community interaction (Section 6.2).

6.2 Draft Proposal to Expand NSO Programs and Community Interaction

During FY 2010, NSO will continue to pursue its current EPO program outlined above. To enhance the program and to begin addressing NSO outreach in Hawai'i, NSO is developing a plan for an active program to deliver ATST-related solar physics activities to a range of Hawaiian and national audiences, including traditionally under-served populations. We have identified population areas that are rich in underrepresented groups or regions we wish to reach, and potential partners and resources through which activities can be delivered. Financing the plan will require a proposal to NSF and other possible sources.

As lead agency on ATST, the NSO plan needs to help cultivate a future workforce on Maui as well as broaden participation among underrepresented groups throughout the U.S. Mainland. NSF identifies these groups as African Americans, Hispanics, Native Americans, Native Hawaiians (because of the location of ATST), and women. NSF further identifies the middle schools as a key area to address with respect to the in retaining students in science. The desired long-term outcome comprises increased public appreciation of and support for solar physics as well as a broader choice of employee candidates for NSO.

The island location of ATST will require a local work force. At the same time, ATST will be a national facility, so its expanded EPO program must also serve the Mainland population. The scientific content will be consistent, but will be optimized to meet the cultural experiences of diverse groups. A significant aspect of the ATST EPO plan will be coordination with Maui Community College and University of Hawai'i IfA to help develop both scientific and technical skills to produce a well-trained diverse local workforce. A major goal in 2010 is to explore the possibilities of how NSO can contribute to current efforts on Maui, such as the Akamai program and the IfA mentoring programs.

Plan: NSO anticipates a 6- to 9-month activity in FY 2010 to develop a full partnership and a complete proposal for submission to NSF. The initial plan will be vetted within NSO and reviewed with the Education Oversight Committee. The next steps will be to develop contacts with potential partners, define their roles, and identify costs (salaries, overhead, other expenses) and build a complete cost plan.

NSO does not propose building a new education facility. Few schools have funds or free time for students to make extended field trips. The best possibilities for success lie in mobile resources, such as taking the Sunspot Solar System Model to schools as The Sun on Wheels, offering Web-based virtual experiences, or providing exhibits and instructor training to complement existing science-oriented venues. Resources in the identified areas will be important as cultural brokers, local agents already known to the community and who can introduce NSO activities to the local population.

Location: NSO will focus initially on four geographic areas with significant populations of under-served groups and existing resources (facilities, science centers, other education venues) through which NSO can present its materials:

- **Maui**: This is a prime audience because Maui residents, both native and non-native, form the population base from which NSO hopes to draw the future ATST work force. Potential partners include the University of Hawai'i Institute for Astronomy, Maui Community College, and the Maui Digital Bus Project.
- **Huntsville-Nashville**: This area has significant African American and Hispanic audiences. Potential partners include the University of Alabama in Huntsville, Alabama A&M University, Fisk University, and Vanderbilt University.
- Las Cruces: The Las Cruces area of New Mexico has a large, diverse Hispanic population and a Hispanic-serving university, and New Mexico State University (also an AURA member) is active in astronomy education. A potential partner is the Gadsden Independent School District, serving parts of two New Mexico counties and part of El Paso.
- **Tucson**: NSO and the National Optical Astronomy Observatory (NOAO) have significant education contacts with Hispanic, Native American, and other education communities.

The age ranges to be served span K-12, college, and adults. Tapping the potential watershed of students cannot be addressed in schools alone since family involvement in informal education activities is also important in identified groups. In addition, delivering ATST-related educational materials through space and science camps in Huntsville, Alamogordo, and Las Cruces/Upham, NM, will provide a unique opportunity to reach national audiences since many of the attendees are from outside the regions where the camps are located.

Staff: NSO envisions a modest staffing increase to execute this program.

- <u>EPO officer</u>: This position is now filled by Dave Dooling. He has been with ATST since October 2002. His duties include developing new education materials and curricula, graphic design of conference materials, writing press materials, and various publications, and EPO planning.
- <u>Educators</u>: Two educators will be needed, one each on Maui and the Mainland. These will be certified science or math teachers who can help develop new activities and align them with education standards. The educators will be required to be on the road for a significant part of the year to deploy activities to schools (the Mainland educator will be fluent in Spanish). Both will be required to work in the RET program at Tucson or Sunspot for at least one summer.
- <u>Summer students</u>: Two REU students (from science education or science communications) will work in curriculum development each year.
- <u>Hands-on Optics</u>: NOAO's HOO program has been highly successful and will be employed in ATST. NSO anticipates employing the services of the HOO staff for two FTE years to adapt existing HOO and other (optics bench) activities to an ATST/solar observing context.

Content: One aspect of broadening participation among underrepresented groups is to provide interesting, science-based activities that motivate them to follow educational paths in science and engineering that lead to jobs with NSO. An important factor to consider in delivering EPO on Hawaii is that much of the science education provided on the islands is oriented towards the environment.

In particular, Hawai'i's Science Content Standards lists *Malama i ka 'Aina: Sustainability* as a key part of <u>Domain II, Strand I: What We Know About the World Around Us, Historical Perspective</u>. This is not out of step with environmental issues faced on the Mainland. Therefore, ATST EPO must incorporate them to the extent practical and sensible. Education areas include:

- <u>Need</u>: First and most important, NSO must establish with the audience why it is important to study the Sun (and why from Earth and why from Haleakalā).
- <u>Magnetism</u>: The prime justification for ATST is to understand solar magnetism, admittedly one of the more difficult concepts to put across to students and the public.
- <u>Optics</u>: NSO will build on the existing NOAO Hands-On Optics program and the optics activities developed at the Exploratorium and other science centers to explain how ATST will dissect sunlight and extract from it the story of how active regions form and shed their energies.
- <u>Computers</u>. The proposed activity will allow students to use computers to manipulate and analyze solar images and data. As much as possible, NSO will select or develop open-source, platform-independent software so schools with computers can use the programs without incurring additional costs.
- <u>Interdisciplinary aspects</u>: In line with the need to address environmental issues, NSO will develop activities that discuss how solar activity is interconnected with life on Earth and how it interacts, starting at a quantum level and ranging up to climate change.

These education areas will touch many grade levels and complement each other. Activities will also be designed for delivery on the Web as podcasts. A venture that NSO is developing is an online lecture series about solar physics challenges and careers. These are to be offered through colleges as a colloquium lectures.

Assessment: NSO will develop survey tools that can be applied to provide a baseline understanding of public knowledge of solar science and develop pre-post-visit tools to assess the impacts of deployed activities. Special attention will be given to ensuring that the materials presented to various audiences are culturally appropriate while providing data sets that can be compared and consolidated. A key element of the ATST education initiative will be assessments to determine its effectiveness and impact. Some long-term impacts—primarily expanded staffing by Maui residents—cannot be known for decades. Others, such as public knowledge about the Sun, can be determined in the short run.

6.3 Broadening Participation and Increasing Staff Diversity

In accordance with the AURA action plan to respond constructively to the NSF goal of broadening the participation of underrepresented groups, the NSO has appointed a Diversity Advocate and adopted a set of near-term and long-term goals in this vital area. AURA has established a Workforce and Diversity Committee that includes each AURA center's Diversity Advocate as a permanent member. The reader is referred to the AURA Web site for an overview of the meaning of "broadening participation" and its action plan. The NSO goals are guided by input received from our oversight committees that also take into account our resource constraints in effectively addressing this area of national concern. Despite limited resources, the NSO has and will continue to make important contributions to broadening participation in the science, technology, engineering and mathematics (STEM) workforce. Our near-term and long-term goals are given in the following:

Near-term goals:

• Expand recruitment efforts of underrepresented groups through broader advertising venues for NSO job opportunities.

- Participate in STEM-related society meetings, either national or regional, serving underrepresented communities such as the National Society of Black Physicists (NSBP), National Society of Hispanic Physicists (NSHP), Society for the Advancement of Chicanos an Native Americans in Science (SACNAS) and American Indian Science and Engineering Society (AISES).
- Add a scientific staff member from an underrepresented group to the NSO Scientific Personnel Committee.
- Continue PAARE student participation in the NSO as funded by the Fisk/Vanderbilt and NMSU PAARE proposals, as well as graduate student participation in the NSO through the Fisk/Vanderbilt Masters-to-PhD Bridge program. Expand this beyond the scientific staff to include our engineering and technical staff as mentors.
- Identify more mentors among the engineering and technical staff in addition to the scientific staff.

Long(er)-term goals:

- Increase the number of students from underrepresented groups in the NSO REU program, ideally, with a supplement in our REU funding.
- Expand the RET program effort by targeting teachers at underrepresented minority-serving institutions, including getting funding for more RETs.
- Increase the number of underrepresented minorities on the scientific and/or engineering/technical staff during the next 3 to 5 years.
- Obtain student internships for engineering and computing at the NSO.

We are pleased to say that progress is already being made in these areas. In particular, a Fisk/Vanderbilt Masters-to-PhD Bridge program graduate student has joined the NSO this past summer for work on GONG and SOLIS instrumentation, respectively, and as previously mentioned, he is now working on a Master's thesis on flare excitation of high- ℓ *p*-modes based on archived GONG data. In addition, we have just hired an African-American who just received his PhD in physics from Howard University to carry out a project supported by a NASA HMI grant. One of our female scientific staff members (untenured) has been added to the NSO Scientific Personnel Committee. In addition, the NSO is represented at selected meetings of science and engineering society meetings that serve underrepresented groups.

7 FY 2010 PROGRAM IMPLEMENTATION

With the ATST construction phase scheduled to begin during FY 2010, challenges to NSO include reorganizing its base programs to permit the transition of personnel to ATST construction tasks, preventing the loss of essential personnel as we pursue a new NSO headquarters location, and continuing the pursuit of increased diversity and educational outreach. Because of these challenges and to achieve economy of scale in other areas, NSO is reorganizing parts of its management structure to accommodate immediate needs during the transition to construction and to begin an evolution toward the structure we anticipate having when ATST becomes operational. Other considerations driving the new organization include ramping up support for SOLIS, reducing the cost of GONG to meet the recommendation of the Senior Review, and the plan for NSO to take on some of the ATST Instrumentation Work Package, including the polarization modulation and calibration unit, the coudé room benches and optical layout, camera systems and detectors, one of the first-light instruments, and the wavefront correction package. Many of the technical and scientific staff who have supported instrumentation and operations at the Dunn Solar Telescope will transfer to ATST, creating a need to reorganize the Sacramento Peak staff.

During this period, NSO needs to continue its strong support of the solar community while using current assets to develop ATST instruments, to test ATST operational concepts, and to train personnel on the multi-instrument, high-data output expected with ATST.

7.1 Organization

NSO is proposing some major changes in its organization. Until recently, NSO has been managed in four major functional units, NSO/Sacramento Peak (NSO/SP), NSO/Tucson (NSO/T), NSO/GONG, and NSO/ATST. The SOLIS program has been a major part of the NSO/Tucson program. NSO conducts operations and projects with a combination of positions funded from its base NSF support, other revenues, positions funded from projects and grants, and positions funded by its colocated partner organizations. (Here we use "base support" to mean those funds NSO receives to conduct operations and instrument programs at its current telescopes and to distinguish them from ATST MREFC funds). 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 maintenance support of the NSO/Kitt Peak facilities provided by KPNO, are in the NSO budget and are shown on the spending plans in Section 7.3.

7.1.1 Director's Office

The NSO Director's office consists of the Director, a Deputy Director responsible for Tucson operations, an Executive Administrative Manager, and it also receives financial and budget support from the NSO/SP facilities manager. The Director, Stephen Keil, currently resides at NSO/SP and also serves as the ATST Project Director. The NSO Deputy Director, Mark Giampapa, serves as site director for Tucson and oversees operations there and has served 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.

7.1.2 NSO/Sacramento Peak

NSO/SP operates the Dunn Solar Telescope on Sacramento Peak and provides some maintenance support for the Evans Solar Facility. NSO/SP will undertake several ATST work packages during ATST construction. In addition to telescope support, the staff at SP supports an office building, library, 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. Rex Hunter is responsible for buildings and grounds, administration and business functions. Rimmele and Hunter report to the NSO Director. As we begin ATST construction, Hegwer will move to the ATST Instrument Engineer position, Rimmele will move to an Associate Director position to lead the instrument packages that will be undertaken at Sac Peak (~\$20M effort, including the wavefront correction package) and he will continue as ATST Project Scientist. Han Uitenbroek has been appointed DST Telescope Scientist and Craig Gullixson is the new DST Project and Telescope Manager. Several other technical personnel that have supported the DST and projects at SP will move to ATST positions. We will hire replacements for some of these positions but not all. With the reduction in technical staff, we will reduce or eliminate new projects at the DST in order to concentrate on science operations with the newly completed suite of diffraction-limited instruments and support for testing of ATST instrument technologies.

7.1.3 NSO Tucson and NSO GONG

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 support from Priscilla Piano as Administrative Manager. McMath-Pierce operations and projects are led by a telescope scientist, Matt Penn, who reports to the Deputy Director. Project and Telescope Manager Kim Streander also reports 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.

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 Program Scientist Frank Hill. Program Manager George Luis is responsible for daily GONG operations and reports directly to the Program Scientist. In order to achieve increased support of SOLIS and some economy of scale with GONG, NSO plans to merge the SOLIS and GONG programs into a single synoptic program under Frank Hill, who will become Associate Director for Synoptics. We will approach the merger in multiple steps, starting with the data handling and processing, followed by combining the technical staff.

7.1.4 NSO ATST

NSO/ATST has been funded primarily by the ATST D&D proposal and funding received to bridge the period leading up to the start of construction. The NSO Director currently serves as ATST Director. Project Manager Jeremy Wagner and Project Scientist Thomas Rimmele report to the Director. The ATST staff members reside in Tucson, at Sacramento Peak, and now in Hawai'i, allowing the team to interact with NSO operations and projects. As ATST enters the construction phase, the staffing will ramp up with lead engineers taking responsibility for the various work packages. As noted, some NSO personnel will transfer full time to ATST construction while others will work part time for the project.

7.1.5 Organizational Chart

A summary organizational chart is shown in Figure 7.1. Some of the details of the GONG-SOLIS merger are still pending and that portion of the chart should evolve during FY 2010. 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 divestment of current facilities as ATST reaches completion. 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 and instrument programs.

7.2 NSO Future Organization

During the ATST era, the NSO will reorganize to support ATST operations on Maui and maintain healthy synoptic and instrument programs. NSO will no longer operate the DST on Sacramento Peak and the McMP on Kitt Peak. NSO plans to consolidate its workforce at a location that provides an optimal management focus for the Advanced Technology Solar Telescope era and benefit the growth of the solar research community. NSO will also move part of its work force to Maui, in addition to new hires on Maui to operate the ATST.

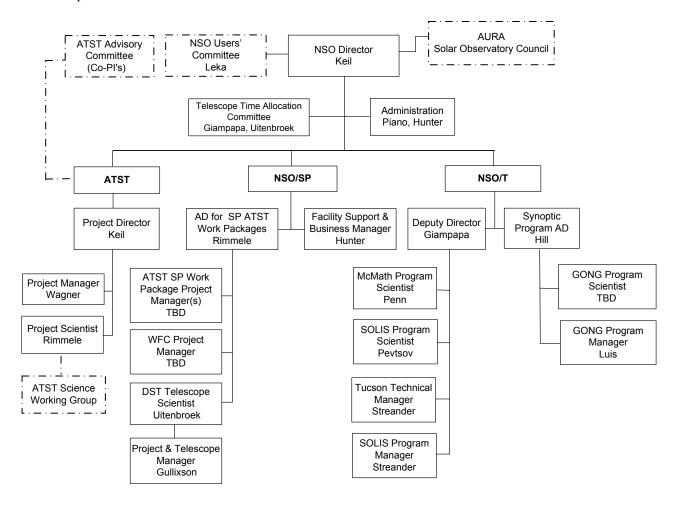


Figure 7.1. NSO Transitional Period Organizational Chart

7.2.1 Headquarters (HQ) Solicitation

Once ATST construction begins, proposals will be solicited by AURA to serve as the host site for the National Solar Observatory. Eligible institutions will include universities, or consortiums of institutions that include at least one university in their membership. The principal objective of the solicitation is to achieve the consolidation of the respective NSO scientific staff presently located at Sunspot, New Mexico, and Tucson, Arizona at a single location associated with a university or a consortium that includes university members. An equally critical objective is to establish a mutually beneficial, collaborative partnership between the NSO and the host organization that will lead to an increase in the number and diversity of faculty and students that carry out research and education in solar physics and closely related fields.

The solicitation will include a pre-letter of intent briefing, the due date for required letters of intent, and the deadline for the full proposal. The requirement for letters of intent is to allow for the expeditious formation of a proposal review panel. The briefing is intended to provide a common forum where further information about the NSO will be provided and questions addressed from potential proposers. Attendance at the briefing will be at the expense of the attendees. Letters of intent do not obligate institutions to submit a proposal. However, proposals will be reviewed only from those organizations that have submitted letters of intent.

The schedule for relocation will allow for an orderly ramp down and withdrawal from current NSO sites such that the world solar community will not lose access prematurely to the solar telescope facilities of the NSO. AURA may elect to discontinue the solicitation process at any point, re-open a solicitation process, or not make a selection if it is deemed in the best interests of the NSO.

7.2.2 Estimated Costs

The exact costs of establishing a new HQ location for NSO and operations on Maui are yet to be determined and will depend on many factors including HQ location, proposed support from the host institution, and programs that will be supported in the ATST era. However, it is worthwhile for future planning to have some rough cost estimates to understand the magnitude of the required planning. Table 7.2-1 presents some cost estimates based on several factors, including the cost of land on Maui, typical building costs, moving costs to Maui and within the mainland, and experience with the removal of facilities. We await a full evaluation of the cost of closing current facilities that is planned by the NSF.

Table 7.2-1. Estimated Cost of Operations on Maui & Establishing a New NSO HQ						
Item		Low	High			
Relocation Costs						
Maui Base Facility						
Land Purchase	Land adjacent to IfA on Maui	\$1,000,000	\$2,000,000			
Building Cost	12,000 sq ft @ \$400-\$500/sq ft	\$4,800,000	\$6,000,000			
Headquarters Facility						
Land Costs	??					
Building Cost	25,000 sq ft @ \$250-\$350/sq ft	\$6,250,000	\$8,750,000			
Staff Relocation						
To Maui	Relocating 25-35 personnel	\$650,000	\$1,000,000			
To Headquarters	Relocating 50 personnel	\$500,000	\$600,000			
Equipment to Maui	Vehicles, optics, instruments	\$500,000	\$550,000			
Equipment to HQ	Electronics, optics, machine tools, computers, data archives	\$500,000	\$550,000			
Closure Costs						
Deconstruction of Sac Peak						
Building Removal		\$2,500,000	\$2,500,000			
Ground Restoration		\$500,000	\$500,000			
Hazardous Material Cleanup	Mercury, oil and gas spillage	\$200,000	\$200,000			
Kitt Peak		,	,			
Mothball McMP		\$200,000	\$200,000			
Relocation of SOLIS		\$550,000	\$750,000			
	Total	\$18,150,000	\$23,600,000			

Many assumptions go into Table 7.2-1. The "low" and "high" columns reflect the uncertainty of several of the estimated costs. Part of university proposals to host NSO may include a building that NSO can lease.

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This transfers the cost from relocation to operations and can spread it out over many years. NSO will need an operating location on Maui to house administrative staff, computing facilities, engineering and maintenance crew, and an outreach program that is off the summit at a suitable location. This Maui base facility would ideally be at or near the University of Hawai'i IfA Advanced Technology Research Center (ATRC) to take advantage of shared facilities and services. The cost estimate for the land on Maui is based on an existing parcel of land adjacent to the ATRC. AURA is thinking about buying this land and constructing a building that would be leased to NSO to recover AURA's cost.

Relocation costs include shipping of household goods and vehicle, a stipend for temporary housing, travel to Maui, etc.

7.3 FY 2010 Spending Plan

The NSO spending plan is based on receiving the President's budget. Any reductions from this amount will initially be addressed with the Director's reserve. Deeper cuts will require program reductions.

7.3.1 Total Budget

Table 7.3-1 summarizes the funding NSO expects to receive as new NSF funding, along with our normal annual revenue for support of operations in FY 2010. The NSO program plan described in Sections 3-6 was developed based on receiving \$9,100K of NSF funding for the NSO base program in FY 2010, as well as a combined \$146M in American Recovery and Reinvestment (ARRA) funds and \$17M in MREFC funding for the ATST. The spending plan also anticipates the transfer of some NSO personnel to ATST construction during FY 2010. The ATST program was conducted during the first few months of FY 2010 using \$3.1M of ARRA funding (as described in Section 5). NSO receives additional operational support from the Air Force Research Laboratory, under an MOU between the AF and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NSO earns revenue from operation of the cafeteria, the Visitor Center, and housing on Sacramento Peak used to support the respective functions.

Table 7.3-1. NSO FY 2010 Funding	
(Dollars in Thousands)	
NSF Astronomy Division Funding	9,100
AFRL Support for Sac Peak Operations	400
NSF REU/RET Program	132
Revenue (Housing, Kitchen, Visitor Center)	171
Programmed Indirects/Carryover	156
ATST Fellowship Support	50
Total NSO Funding	10,009

In addition to the funds shown in Table 7.3-1, NSO receives funding through a variety of grants and contracts with both NSO and non-NSO principal investigators. These funds are used to hire research fellows for specific programs, support visiting PIs and students, and to enhance capabilities needed for these programs. The enhanced capabilities are then normally made available to the user community. Table 7.3-2 shows NSO's currently active grants and contracts.

The funding shown in Table 7.3-1 is allocated to the various programs NSO conducts to fulfill its mission. Table 7.3-3 shows the program areas in which funds will be expended, and those are further broken down into the work packages within each funding area (telescope operations, instrumentation, administration, EPO, etc.). The table also shows how we apply the revenue and some of our indirect cost earnings to cover expenses not covered by the NSF new FY 2010 funding. Funding that NSO provides NOAO for business

Support has been prorated to each program area by the number of personnel and office space supported. Note that office space at Sac Peak is supported under facilities at Sac Peak and the NOAO support for Sac Peak is primarily HR, accounting, and contracting.

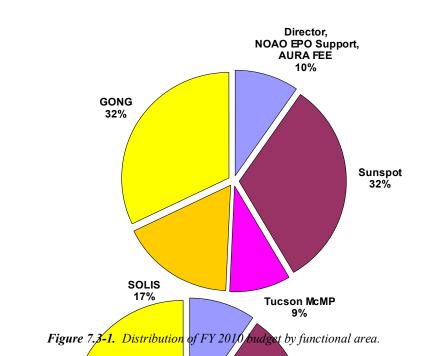
Figures 7.3-1 and 7.3-2 show how NSO funding is divided among the various programs and respective work packages. From Figure 7.3-1 it is seen that SOLIS and GONG, which are NSO's primary synoptic programs, are a substantial part of our base program. By combining these over the next year into a single program, we will achieve some economy of scale and funds received from non-NSF sources for GONG operations will free funds to ramp up SOLIS and ATST operations as outlined in NSO's Long Range Plan.

Proposal Title	Source	Term	PI	Program	FY 2010	Total Grant
Proposal to NSF International Research Experiences for Students	NSF/IRES	2010-2012	Hill/Jain	GONG	50,000	150,000
A Next Generation Model of the Corona and Solar Wind	NASA sub-award via SAIC	2007-2011	Harvey	SOLIS	16,000	64,000
3D Magnetic Fields: The Dynamic Scaffold of the Solar Atmosphere	NASA SR&T LWS	2008-2010	Harvey/Norton	SOLIS	132,355	421,307
Incorporation of a Generalized Data Assimilation Module within a Global Photospheric Flux Transport Model	AFOSR	2008-2010	Harvey/Henney	SOLIS	17,500	52,500
Data Services Upgrade for SOLIS/VSM Stokes Profile Data	NASA ROSES	2010	Harvey/Henney	SOLIS	48,761	48,761
A Study of Seismic Signatures of Active Regions in Farside Imaging for Applications to Space-Weather	NASA LWS TR&T	2008-2010	Hill	GONG	121,834	247,327
Helioseismic Studies with MDI	NASA GIP	2007-2010	Hill	GONG	266,677	791,642
Observing Support at the McMath- Pierce Solar Telescope	NASA	2007-2011	Giampapa	McMP Observing	24,800	49,300
Solar Magnetic Fields during a Deep Minimum of Solar Cycle	NASA Solar/Heliospheric SR&T	2009-2011	Pevtsov		184,596	374,101
Hinode Support (Sac Peak collabo- ration w/ Lockheed)	NASA sub-award via Lockheed	2008-2010	Rimmele	Hinode Support	113,333	340,000
A Facility for High-Resolution Spec- troscopy: Lboaratory and Ground- based Observations in Support of Upper Atmospheric Research	NASA UARP	2009-2012	Giampapa	McMath-Pierce FTS	115,000	355,454
Adding H α to the GONG Instruments as a Backup System for the AF Weather Agency's O-SPAN Space Weather Network	AFOSR	2009-2010	Hill	GONG	650,000	650,000
Development of the Virtual Solar Observatory (VSO)	NASA	2010	Hill	VSO	254,801	254,801
Support for the Improved Solar Observing Optical Network (ISOON) at NSO/SP	AFOSR	2008-2011	Radick/Keil	ISOON	69,000	69,000
				TOTAL	2,064,657	3,868,193

	Director's			Tucson		
	Office Sunspot	SYNC	SYNOPTICS			
Expenses			McMP	GONG	SOLIS	
Director, Staff, Committee Support	418					418
Scientific Staff		660	155	923	362	2,099
Scientific Support/Computing		313	26	708	204	1,251
Instrument Development Maintenance/Telescope Operations		979 296	208 201	287 669	454 264	1.928 1,430
Facilities		665				665
Administrative Support		296	94	201	63	654
Educational & Public Outreach	108^{1}	158	66			332
NOAO Business Support ²	45	173	154	269	211	852
ATST Fellowship ³		50				50
AURA Management Fee	331					331
Program Total	903	3,589	903	3,056	1,558	10,009
Revenue						
Programmed Indirects/Carryover	(24)	0	0	(132)		(156)
Housing Revenue		(104)				(104
Meal Revenue		(17)				(17)
NSF REU/RET Funding		(66)	(66)			(132
Air Force Support		(400)				(400
ATST Fellowship Support		(50)				(50)
Visitor Center Revenue		(50)				(50
NSF/AST Funds	879	2,902	837	2,924	1,558	9,10

Table 7.3-3. NSO Spending Plan

¹ These funds are transferred to NOAO to support mutual EPO programs. ² These funds are transferred to NOAO for HR, accounting, contracting and facilities services. ³ AURA provides support for cost sharing of an ATST Fellowship.



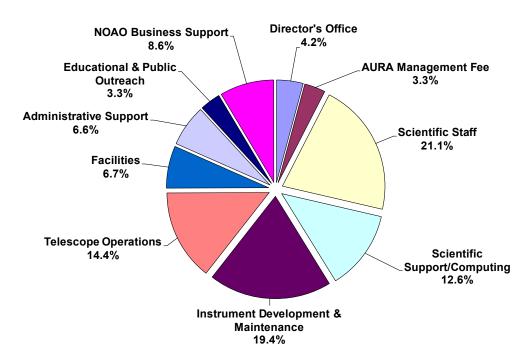


Figure 7.3-2. Distribution of NSO budget by tasks.

7.3.2 Work Package Break Out

Tables 7.3-4 to 7.3-10 show the spending plan for the major functional areas in more detail, breaking out payroll and non-payroll by work packages.

7.3.2.1 Director's Office

Table 7.3-4. Director's Office						
(Dollars in Thousands)						
	FTEs	Payroll	Non-Payroll	Total		
Staff	2	380	22	402		
Committees			12	12		
NOAO Support			46	46		
AURA Management Fee			331	331		
Reserve			4	4		
Outreach Support from NOAO			108	108		
Total Director's Office	2	\$380	\$523	\$903		

Table 7.3-4 presents the Director's office budget. As seen in Table 7.3-3, \$24K of the indirect amounts earned from non-NSF funded projects is budgeted towards operation of the Director's office.

Staff included in the Director's office budget are the Director and an Executive Administrative Manager. As noted earlier, the Deputy Director's salary is included in the Tucson budget. Non-payroll expenses include travel, supplies and materials, and other miscellaneous expenses incurred by the Director.

Committees include the semi-annual meetings of the Users' Committee and support for other committee meetings as needed to support management of the observatory.

NOAO support includes support for office space for the Director and Executive Administrative Manager in Tucson, HR, and accounting.

The AURA management fee line item is based on the full NSO base budget. It covers management support provided by AURA, including the Solar Observatory Council (SOC), which provides both management oversight and program advocacy.

The outreach support from NOAO goes to the NOAO Public Affairs and Educational Outreach division and covers support received from PAEO for various outreach programs.

7.3.2.2 Tucson Programs

Tables 7.3-5 through 7.3-7 show the budget breakdown for Tucson and support for the McMath-Pierce Solar Telescope (McMP) facility, SOLIS and GONG. Support for the McMP and SOLIS programs is highly integrated under a single technical program manager. When resource conflict issues arise, the highest priority is assigned to getting SOLIS fully online.

Table 7.3-5. NSO/Tucson/McMP								
(Dollars in Thousands)								
	FTEs	Payroll	Non-Payroll	Total				
Scientific Staff	1.1	146	9	155				
Science Support/Computing	0.2	23	3	26				
Instrument Development	1.85	163	45	208				
Telescope Operations	1.70	125	76	201				
Administration	0.48	88	5	94				
NOAO Support			154	154				
Outreach (REU/RET)		50	12	64				
Total Tucson/McMP	5.33	\$595	\$304	\$903				

The Tucson/McMP staff provide support for operations on Kitt Peak and for instrumentation and maintenance of the McMath-Pierce Solar Telescope. The NSO Deputy Director has 20% of his time for research, split between Tucson/McMP and SOLIS, and 80% for management of programs in Tucson, where he acts on behalf of the Director.

The 1.1 FTEs of scientific staff provide support of programs at the McMP, including the NSO Array Camera (NAC) IR program, support for the California State University at Northridge integrated field unit (IFU), and support for the Fourier Transform Spectrometer (FTS). They also support related student programs and outreach. 10% of the Deputy Director's time is included in this line item.

A nominal amount of programming time is used at the McMP to upgrade the current tracking and control systems.

The instrument development effort is primarily devoted to interfacing the IR adaptive optics to the McMP main spectrograph and the NAC.

Telescope operations consist of support for visiting and staff astronomers at the telescope, support for installing upgrades and general telescope maintenance.

Administrative support is provided by the Deputy Director and the Director's Executive Administrative Manager.

NOAO support consists of office laboratory support in Tucson, human resources, accounting, vehicles support, shops, and janitorial services. Not listed because it is part of the NOAO/KPNO budget is general

maintenance support on the summit of Kitt Peak, road upkeep, cafeteria services, etc. These costs are in the KPNO budget per the memorandum of agreement of 2000, when NSO separated from NOAO.

	Table 7.3-6. NS	O/SOLIS					
(Dollars in Thousands)							
	FTEs	Payroll	Non-Payroll	Total			
Scientific Staff	2.6	341	21	362			
Software Support	1.8	197	7	204			
Instrument Development	4.15	454	0	454			
Telescope Operations	1.3	63	201	264			
Administration	0.32	59	4	63			
NOAO Support	0		211	211			
Total SOLIS	10.17	\$1,114	\$444	\$1,558			

Outreach funding is primarily for REU and RET participants that are supervised by the NSO/Tucson scientific staff, including those positions listed under SOLIS and GONG.

Currently there are two unfilled SOLIS scientific staff positions. One of these will be filled in February and the other is being advertised. In addition to the 2.6 FTEs, SOLIS is now receiving support from one of the Sac Peak scientists who will serve as SOLIS Program Scientist. The 2.6 FTEs includes a 0.5 FTE SOLIS Instrument Scientist. Scientific staff contributions include instrument debugging and developing methods for reducing SOLIS data. Of particular importance has been the development of inversion techniques for recovering vector magnetic fields from the polarization data.

Software support includes both instrument control and establishing the data pipeline. SOLIS data are reduced daily and added to the NSO Digital Library, where it can be downloaded by the solar community. Daily products include full-disk vector magnetograms, line-of-sight magnetograms, high-resolution active-region vector magnetograms, chromospheric magnetograms, and ISS spectra.

Instrument development is aimed at upgrading the VSM cameras and modulators and completing the fulldisk patrol imager.

Telescope operations staff provide support for the daily operation of SOLIS.

Administrative support is provided by the Deputy Director and the Director's Executive Administrative Manager.

NOAO support consists of office laboratory support in Tucson, HR, accounting, vehicles support, shops, and janitorial services.

	Table 7.3-7. N	ISO/GONG					
(Dollars in Thousands)							
	FTEs	Payroll	Non-Payroll	Total			
Scientific Staff	7.5	893	30	923			
DMAC Operations	7.0	581	127	708			
Instrument Development	1.5	158	128	287			
Telescope Operations	4.5	370	299	669			
Administration	2	191	10	201			
NOAO Support			269	269			
Total GONG	22.5	\$2,193	\$863	\$3,056			

Table 7.3-7 summarizes the GONG spending plan for FY 2010. 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.

The GONG scientific staff includes a GONG Program Scientist who leads the program and reports to the Director, but also receives support from the NSO/Tucson Deputy Director. The 7.5 FTEs include an 0.5 FTE Instrument Scientist. The remaining 6.0 FTEs provide support for the various GONG science products that are distributed to the solar community. These include data probing the solar interior, synoptic maps, and more recently sub-surface layer dynamics and magnetic field measurements of the full disk.

The Data Management and Analysis Center (DMAC) staff collect, process, and distribute the GONG data.

The instrument development staff are currently using Air Force funding to develop an H-alpha capability for GONG in anticipation of AF operational support for the GONG network.

The telescope operations staff provide operational and maintenance support for the GONG network. This includes yearly maintenance visits to the network sites.

The administrative staff consists of a Program Manager, who manages the GONG program and reports to the GONG Program Scientist, and an administrative assistant.

NOAO support consists of office and laboratory support in Tucson, HR, accounting, vehicles support, shops, and janitorial services.

Once the merger of SOLIS and GONG is complete, NSO will formally appoint a Synoptic Program Director to oversee the combined program.

Table 7.3-8. NSO/SP							
(Dollars in Thousands)							
	FTEs	Payroll	Non-Payroll	Total			
Scientific Staff	4	620	40	660			
Science Support/Computing	3	198	115	313			
Instrument Development	10	832	147	979			
Telescope Operations	3	270	26	296			
Facilities	5	281	383	665			
ATST Fellowship	1	50	0	50			
Administration	4	272	24	296			
NOAO Support	0	0	173	173			
Outreach (REU/RET), Visitors	2	108	46	154			
Total NSO/SP	32	\$2,631	\$954	\$3,585			

Table 7.3-8 breaks out the Sacramento Peak operations budget. A portion of the scientific staff supports the Dunn Solar Telescope, participates in instrument development, ATST design and development, and conducts research. The DST Program Scientist oversees telescope operations and projects and supervises the NSO/SP Technical and Telescope Operations Manager. The scientists support the TAC process and observatory operations (library, outreach, instrument program, modeling, and users). The ATST fellowship supports an ATST postdoctoral position that is cost-shared with AURA.

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The instrument development staff support 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. Some of the instrument development staff will transfer to ATST construction, and a few of the most critical skills will be replaced.

Telescope staff operate the DST, provide user support, help with instrumentation installation and interfaces, and perform maintenance on the telescope. The telescope is allocated and operated on all but two days out of the year, weather permitting.

The Sac Peak administrative staff oversee general site maintenance and daily site operations, logistical 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 revenue), water and sewage treatment, site snow removal and road maintenance. NOAO support includes HR, accounting, contracting, and some legal support.

Outreach includes REU and RET support, public outreach programs, operation of the Sunspot Astronomy and Visitor Center.

Table 7.3-9 contains the \$400K contribution from the U.S. Air Force 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 7.3-9 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 7.3-9. 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	\$400				

7.4 Funding Priorities

NSO is totally committed to developing the ATST. In order to accomplish this during the ATST design and development phase, while still maintaining a healthy national solar research program, NSO developed a program that generated substantial in-house ATST investment and support. 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 the technical program for the ATST. During ATST construction, NSO personnel that work on ATST work packages must charge their time to the ATST construction phase budget. NSO staff on base NSO support will continue working toward ATST operations planning and developing the skills and techniques needed to operate and fully exploit the ATST. They will do this by using existing NSO resources such as the DST and McMP. One of the tasks will be to begin developing the data center and software needed to manage ATST data. Given the need to maintain a U.S. presence in solar physics and the goal of developing a sound ATST operations plan, NSO has prioritized its efforts as follows:

- Restructure base-funded project activities at NSO/SP to focus on skills and technologies needed for ATST operations and to begin thinking about ATST second-generation instrumentation. NSO/SP is concentrating on MCAO and multi-instrument support, while aggressively seeking partners and funding for any new instruments or upgrades to existing facilities. NSO has delayed, or postponed indefinitely, some non-critical maintenance items. NSO/T is concentrating on IR development and high-resolution imaging and spectroscopy in the infrared.
- Ensure uninterrupted support to the solar community through operation of its flagship facilities until ATST replaces them.
- Develop a three-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.
- Combine the GONG and SOLIS programs to take advantage of synergisms and reduce overall cost of operations.

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

7.5 Infrastructure Plan and Strategic Needs

With the commissioning date and scientific operation of the Advanced Technology Solar Telescope about eight years away, NSO must continue to serve the U.S. solar community with its current facilities and maintain those facilities in a manner that keeps U.S. 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. Additionally, we believe that the facilities at Sac Peak and Kitt Peak will have a life beyond the NSO and our plan is to find parties to which we can transfer these facilities. We have an obligation as a steward of government owned facilities to maintain them at an appropriate level that will allow a suitable transfer to a qualified operator.

The infrastructure plan is designed to address infrastructure needs at the National Solar Observatory that will ensure the viability of current NSO assets to support the solar user community for the next several years until the ATST comes online, and to enhance our synoptic programs. Infrastructure funds are used to support forefront solar research by replacing failing and outdated systems at our telescopes and data handling facilities and to ensure continued safety of operations at NSO's observatory sites. The NSO infrastructure plan takes into account the long-range plan to close the DST and McMP when ATST comes online and to consolidate its staff at a single headquarters location. Thus infrastructure improvements are determined on the basis of maintaining essential first-rate ground-based observing opportunities for the solar community, keeping a safe working environment at the existing observatory sites, maintaining a robust synoptic program, preparing for ATST operations, and ensuring that our facilities are attractive to third parties that may be interested in assuming responsibility for the facilities when NSO begins ATST operations and consolidates its staff.

Because of continued near-level support (often below level, sometimes above, but never sufficient to account for inflation), NSO has limited its small amount of allocated base infrastructure spending to critical items for maintaining safety and telescope operations. It has generated requests for additional funding for larger ticket items and for those maintenance items not covered in exiting budgets. The supplemental

funding received from the American Reinvestment and Recovery Act (ARRA) has permitted NSO to catch up in several areas. We have integrated these into our overall plan.

7.5.1 ARRA Infrastructure Support

At the end of FY 2009/beginning of FY 2010, we received \$1.4M in ARRA funding that will allow us to accomplish several large maintenance and upgrade projects, including some that have been deferred for many years.

Table 7.5-1 ARRA Funded Infrastructure Improvements			
Item	Cost	Description	Status
DST Deformable Mirror Replacement	\$180,000	Replace old AO mirror.	Ordered
Sac Peak Road Maintenance	\$200,000	Maintenance/Safety.	Will bid in spring 2010
SOLIS Tower Clamshell Hydraulic Rams	\$80,000	Replace failing hydraulic system.	Bids received. Vendor contract being negotiated.
MCMP Telescope Control System	\$75,000	Upgrade to modern control system.	Quotes being obtained.
McMath-Pierce Glycol Inspection/Maintenance	\$30,000	Safety – Replace corroded pipes.	Bids received. Inspection scheduled for early Jan. 2010.
GONG Network Site Workstations	\$81,000	Replace site workstations purchased in 1999.	All hardware ordered.
Synoptic Data Processing	\$68,000	Increase capacity of data manage- ment and archive to handle SOLIS and real-time GONG data.	Most of hardware ordered.
DST Basic Infrastructure Needs	\$225,000	Upgrade/replace old equipment; improve safety.	Work in progress
McMP CCD Camera	\$35,000	Upgrade to modern CCD.	In progress
McMP Enclosure Clean and Paint Interior	\$60,000	Maintenance; decrease dust.	Will bid in spring 2010
NSO/SP Workstation Upgrade	\$62,000	Allow rapid reduction of large data sets and modeling.	Purchase orders in preparation.
NSO/SP Local Area Network	\$170,000	Upgrade LAN to handle increased data processing	Purchase orders in preparation.
NSO/SP Server Upgrades	\$50,000	Replace obsolete equipment to handle increased data flow.	Purchase orders in preparation.
GONG Real-Time Data Transfer	\$84,000	Real-time transfer of full resolution GONG data.	Purchase orders in preparation.
Total ARRA Funds	\$1,400,000		

The deferred maintenance items and additional facility funding requested from the ARRA are listed in Table 7.5-1 and were developed in light of the Senior Review, and in the case of the DST and McMP, the planned ramp down and divestiture of these facilities when ATST enters the commissioning phase. The listed items are those we felt were needed immediately to maintain safe and efficient operations over the next five years. These improvements will provide the solar community with the support required to make a successful transition to the ATST era. Most if not all of these items should be completed in FY 2010.

7.5.2 Infrastructure Improvements Completed with FY 2009 Base Funding

In addition to our normal maintenance program, we completed several infrastructure projects with base funding in FY 2009.

NSO/Tucson

• Purchased and installed a roof hatch on the Kitt Peak SOLIS Tower for better environmental control and for improved safety.

- Procured an adjustable-height cart for equipment transfers on and off the main spectrograph table. This addition also addresses a safety issue since it enables one person to safely move equipment on/off the table.
- Replaced the SOLIS Web cameras with more reliable weather-proof cameras.
- Upgraded the desktop computers and/or laptops for SOLIS and McMath-Pierce personnel. This investment improves staff productivity and operational efficiency. For example, observing support staff are now able to use a laptop and the wireless system at the McMath-Pierce to carry out telescope control tasks from anywhere in the building.

NSO/SP

- Purchased a fast CCD camera.
- CMAC replacement project is approximately 90% complete.
- Continued DST dust remediation Completed Phase 2 of the dust remediation project at the DST. This project should be completed in FY 2010.
- Replaced DST uninterruptible power supply (UPS).
- Housing Renovated one relocatable unit and started on another.
- Replaced one snow-blower.
- Replaced two staff vehicles (using special GSA U.S. auto maker stimulus funding).

7.5.3 FY 2010 Plans for Base Funding

NSO/Tucson

Planned infrastructure upgrades for SOLIS and the McMP on Kitt Peak include:

- Upgrade of the McMP/SOLIS UPS to a larger capacity.
- Purchase of a spare for the SOLIS system area network (SAN) on Kitt Peak to remove single point of failure.
- Purchase of a mountain based vehicle for SOLIS/McMP personnel to transfer equipment.
- Purchase of a spare CPU for the SOLIS observing room to remove single point of failure.
- Purchase of replacement tools and tooling for the McMP machine shop and SOLIS.
- Upgrade of McMP network switch to handle increased data load...
- Purchase electronic data logging equipment to improve troubleshooting capability.
- Purchase of binocular microscope zoom and camera guiding system.
- Patch and seal the concrete at the top of the McMath-Pierce to prevent further deterioration and damage.
- Replacement of obsolete desktop PC system for McMP visiting astronomers' use.
- Replacement of McM-P #2 Mirror Hot Air Dispersal System to improve seeing.

NSO/SP

Planned infrastructure upgrades at Sac Peak include:

- Purchase of liquid nitrogen compressor.
- DST Dust Remediation Complete project with final concrete work.
- Replacement of commercial lawn mowing equipment.

- Housing Renovate two to three relocatable houses, including new paint, plumbing fixtures and flooring where necessary.
- Renovation of Director's and ISOON offices, including painting, lighting upgrades, new window coverings.
- Exterior painting of Hilltop Dome, Evans Solar Facility and visitor apartments.
- Replacement of onsite staff vehicle (Ford Taurus Wagon) with new or used Minivan or Wagon.

7.5.4 Unfunded Infrastructure Improvement Requests

While the NSO budget contains sufficient funding to carry out essential routine maintenance, and the ARRA funds are allowing NSO to complete some of the higher priority infrastructure issues, there remains several major infrastructure and maintenance items that are beyond the range of our normal funding. Table 7.5-2 provides an itemized list, by site, with descriptions.

Table 7.5-2 Unfunded Infrastructure Improvements							
(Dollars in Thousands)							
Item	Cost	Notes					
NSO/Sac Peak							
DST Turret Repair	75	Replace obsolete controls and hardware					
Zygo Interferometer	75	Optical testing					
Computer Numerical Controlled (CNC) Lathe	50	Instrument development for SP and ATST					
DST Data Acquisition System	50	Continue upgrade to handle larger, faster CCDs					
Loader	85	Snow removal and maintenance					
Main Lab Boiler Lines and Radiators	50	Replace obsolete heating system, reduce cost					
Apartment Building Boiler Lines and Water Lines	50	Replace obsolete heating and water lines, reduce cost					
Vehicle Replacement	25	Replace older vehicle					
Dump Truck/Snow Plow	65	Replace old truck					
Redwood Building Painting	35	Contract to paint redwood buildings					
Total NSO/SP	560	· · · · ·					
NSO/Tucson							
SOLIS Data Acquisition System Upgrade	11	Reduce operational cost					
GONG Photocopier	5	Replace obsolete copier					
GONG Farm Air Conditioner	8	Replace obsolete unit					
McMP Mirror Refigure	60	Improve imaging					
McMP Optical Tunnel Chiller Compressor	40	Improve internal seeing					
FTS Refurbishment	132	Decrease maintenance					
Total NSO/T	256						

NSO/SP

DST Basic Infrastructure Improvements

Other basic infrastructure investments needed at the DST to upgrade/replace aging equipment, provide safety improvements, and ensure continued smooth DST operations include:

- *DST Turret Repair and Controls Upgrade*. Replace 1960's hardware with digital hardware. Estimated Cost: \$75K
- *Zygo Interferometer*. Enable in house testing of optics and reduce operations cost: Estimated Cost: \$75K
- CNC Lathe. Needed for on-site ATST machine shop work. Estimated Cost: \$50K

• *Modernizing the DST Data Acquisition System (DAS),* i.e., data storage, network, acquisition system (to handle the increased data loads from high-speed large-format cameras). Estimated Cost: \$50K.

NSO/SP Facilities

Historically, the budget for NSO/SP has included approximately \$40K in funds above our normal maintenance program for use on larger "projects." Typically, we saved or carried over some of these funds to accomplish these projects that were beyond our normal budget. With the continuing rise in cost of building supplies, propane, and electricity, and our flat budgets, our discretionary funds have been absorbed into the daily maintenance activities. The size of these projects make them 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 or transfer of Sac Peak in mind, and represents improvements needed in the short term.

- *Equipment Replacement.* Request \$85K: Our current loader is approximately 15 years old. It is heavily used, especially for snow removal, and is experiencing more breakdowns and subsequent downtime. A catastrophic failure would severely impact our ability to complete snow removal and other critical tasks.
- *Main Lab Boiler Line and Radiator Replacement*. Request \$50K: The Main Lab houses the offices of three-quarters of our staff and computing facilities. The facility is over 40 years old and is heated with a hot water system with radiators in individual offices. The boiler was replaced about 15 years ago but remains serviceable. The hot water lines connecting the boiler to the individual radiators and the radiators themselves have never been replaced. We are experiencing multiple failures of these lines each winter and expect that pattern to worsen. A catastrophic failure during the winter months could make the facility uninhabitable for an extended period of time. This project would replace all of the lines and the radiators. Replacement of the radiators with more modern units should increase the efficiency and improve the quality of heat in the building.
- Apartment Building Boiler Line and Water Line Replacement. Request \$50K: The apartment building is our primary source of housing for official visitor and users of the telescopes. As with the Main Lab, the facility is over 40 years old and has had little maintenance to the hot water heating and drinking water lines during that time. Failures are becoming frequent and maintenance costs are rising. This project would replace all the hot water heater lines, radiators and drinking water lines. This will greatly improve the quality of heat in the building and the drinking water.
- *Vehicle Replacement.* Request \$25K: One of our current staff vehicles has well over 100K miles and is 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. Also, with the funding of the ATST and the participation of many of our current employees, our travel to Tucson and other locations will increase dramatically, requiring that all of our staff vehicles be available for use.
- *Dump Truck/Snow Plow Replacement*. Request \$65K: Current dump truck is about 20 years old. As with the loader, it is heavily used for snow removal and is experiencing more problems. Maintenance costs and dependability have negatively impacted our facilities maintenance staff and will continue to grow as it ages. As our main road plow, a catastrophic breakdown during the winter would have a severe impact on our ability to complete snow removal.
- *Redwood Building Painting*. Request \$35K: Redwoods including the apartment building and the community center have not been repainted for approximately 20 years. Paint is beginning to peel and subject the wood exterior to the severe elements at Sac Peak. The wood exteriors will deteriorate fairly quickly in this environment causing more costly repairs in the future.

NSO/T

<u>SOLIS</u>

- *SOLIS Full-Disk Patrol (FDP) Data Acquisition System (DAS) Upgrade*. An upgrade of the SOLIS FDP DAS to a VSM-style DAS would provide the following advantages:
 - The FDP and VSM hardware would be identical, thus reducing the spare parts requirements;
 - At least one VME CPU board (possibly two) would be free for use as a spare for SOLIS;
 - Spare components for the current FDP DAS are almost impossible to find; therefore, the upgrade would resolve this and enable long-term support of the system; and
 - $\circ~$ Software support can be shared between the VSM and the FDP.

Itemization of estimated cost for this upgrade:

- \cdot 1 ea. 3U rack mount server \$3K
- \cdot 2 ea. Pleora iPORT Camera Link to Gigabit Ethernet converters $2.5 \mathrm{K}$
- \cdot 3 ea. RS422 to Camera Link converters (2 + spare) \$1.5K
- GigE to fiber media converters \$1K
- · Misc. cables \$1K
- · 4 ea. Camera Link video splitters (for testing) \$2K
- Total Estimated Cost: \$11K

McMath-Pierce

- *Refigure & Polish the 1.5-m Cervit #2 Mirror for the McMP*. Request: \$60K. The McMP 1.6-m quartz imaging (#2) mirror was damaged in an incident that occurred in the 1970's. The 0.9-m #2 mirror from the West Auxiliary Telescope came free of its mounting and crashed to the bottom of the telescope. The mirror impacted the carriage of the main 1.6-m #2 mirror causing the main #2 to momentarily bounce up out of its mirror cell before settling back into it. In the process, one of the mirror's retaining clips caught the edge of the mirror resulting in a ~8" chip in the edge of the mirror's front surface. A replacement 1.5-m Cervit blank was quickly procured, ground, polished, coated and put into service. It was later realized that the mirror was rushed too quickly through the optical shop which left the mirror with a poor optical figure. The mirror had a badly rolled edge plus a central peak that limited its image quality. In the late 1980's, the original quartz mirror was tested and, with the exception of the chipped region, found to still have a good surface. It was then reinstalled in the telescope and so has been used as the telescope's imaging mirror ever since. Cervit has a lower coefficient of expansion compared to quartz. The focus is currently known to drift by several cm through the day as the telescope mirror warms. Replacing the quartz mirror with Cervit would result in improved focus stability.
- *McMP Subterranean Optical Tunnel Chiller Compressor*. Request: \$40K. The subterranean section of the McMP optical tunnel is lined with refrigerant lines that can be used in the winter to improve tunnel seeing when the cavern's surrounding rocks are deemed too warm compared to the frigid outside temperature. The system is used only occasionally as the rock is normally thought to be close enough to the proper temperature to stabilize the internal seeing. The chiller system utilizes a large compressor that resides in the telescope pump house located just north of the telescope itself. The compressor is of an old design that is less efficient than a modern unit, and is difficult to maintain and find replacement parts for. It has been recommended that the refrigeration compressor unit be replaced. A modern replacement would likely cost somewhere in the \$40K range. More research would be required to better establish the actual cost.

Fourier Transform Spectrometer (FTS)

- *Reference Laser*. note that the current laser is over 30 years old. Zeeman Stabilized HeNe Laser Agilent Technologies Model 5517A. Estimated Cost: \$12K.
- Lock-in Amplifier. Estimated Cost: \$10K.
- *Beamsplitter Recoating*. Note that recoating the beamsplitters is less expensive than replacing them. Recoating would be done by Barr Associates. There are four beamsplitters (UV beamsplitter Al + MgF2; Visible beamsplitter Ag + MgF2; CaF2 beamsplitter GaP; KCl beamsplitter GaAs) at an estimated cost of \$20K each. Total Estimated Cost: \$80K.
- Steering Optics Recoating Al and Ag. Estimated Cost: \$20K.
- Redesign and Fabrication of 8-inch Steering Mirror Mounts (2 ea.). Estimated Cost: \$10K. Total FTS Estimated Cost: \$132K.

GONG

- *High-Quality Photocopier for GONG Mail Room.* The current unit is very old, can no longer make quality copies, and frequently requires expensive service calls. A good durable unit is needed, since many staff members from the west end of the Tucson office building use it. Estimated Cost: \$5K.
- *New Air Conditioning Unit for Tucson GONG Farm Office Trailer*. The current unit is old and needs frequent servicing. Estimated Cost: \$8K.

APPENDICES

APPENDIX A. OBSERVING AND USER STATISTICS
APPENDIX B. ORGANIZATIONAL PARTNERSHIPS
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APPENDIX E. STATUS OF 2009 MILESTONES
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APPENDIX A: OBSERVING AND USER STATISTICS

In the 12 months ending 30 September 2009, 74 observing programs, which included 17 thesis programs, were carried out at NSO. Associated with these programs were 79 scientists, students, and technical staff from 34 US and foreign institutions.

NSO Observing Programs by Typ (US and Foreign)	e	
12 Months Ending September 2009	Nbr.	%Total
Programs (US, involving 1 non-thesis grad		
student & 1 undergrad)	56	76%
Programs (non-US)	4	5%
Thesis (US, involving 3 grad students)	4	5%
Thesis (non-US, involving 14 grad students)	10	14%
Total Number of Unique Science Projects*	74	100%

*Includes observing programs conducted by NSO/NOAO staff scientists.

Users of NSO Facilities by Category								
		Vis	NSO/NOAO Staff					
	US	Non-US						
PhDs	35	24	59	74%	12			
Graduate Students	4	12	16	20%	0			
Undergraduate Students	1	0	1	1%	0			
Other	2 2 4 5% 16							
Total Users 42 38 80 100% 28								

Institutions Represented by Visiting Users**							
US Non-US Total % Total							
Academic	11	11	22	65%			
Non-Academic	7	5	12	35%			
Total Academic & Non-Academic 18 16 34 100%							

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

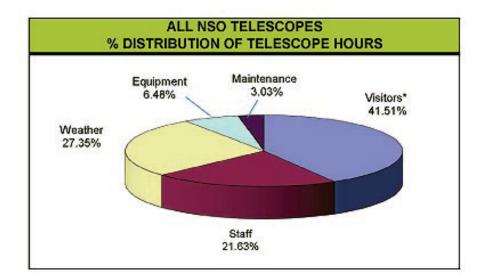
Number of Users by Nationality					
Czechoslovakia	1	Japan	3		
England, UK	2	Mexico	1		
Germany	8	Spain	6		
India	3	Switzerland	2		
Ireland, UK	4	United States	70		
Italy	8				

INSTITUTIONS REPRESENTED BY USERS
Foreign Institutions (16)
Abdus Salam Intnl. Centre for Theoretical Physics
Astronomical Institute Ondrejov, Czech Republic
ETH Zurich
INAF - Arcetri Astrophysical Observatory
INAF - Osservatorio Astronomico di Roma
Indian Institute of Astrophysics
Indian Space Research Organisation (ISRO)
Instituto de Astrofisica de Canarias, Spain
Kiepenheuer Inst. fuer Sonnenphysik, Germany
Max-Planck-Institut fuer Sonnensystemforschung
Queen's University, Ireland, UK
Universidad de Monterrey, Mexico
Universita "La Sapienza" Rome
University of of Köln, Germany
University of Rome "Tor Vergata"
Universtiy of Sheffield, UK
University of Tokyo
US Institutions (18)
Adler Planetarium, Chicago
California State University, Northridge
Dickinson College
Edinboro University
Harvard-Smithsonian Center for Astrophysics
High Altitude Observatory, NCAR, Boulder
Lockheed Martin Solar & Astrophysics Laboratory
Mt. Wilson Observatory
NASA Ames Research Center
NASA Goddard Space Flight Center
NASA Langley Space Flight Center
Ohio State University
Southwest Research Institute, Boulder
University of Arizona
University of Colorado, CASA
University of Florida
Unviersity of Hawai'i, IfA
University of Maryland, College Park
US Air Force/Philips Lab (USAD/PL/GSS)

FY 2009 USER STATISTICS – TELESCOPE USAGE AND PERFORMANCE DATA

In the fiscal year ending 30 September 2009, 41.5% of the total available telescope hours at NSO/Sacramento Peak and NSO/Kitt Peak went to the observing programs of visiting principal investigators; 21.6% were devoted to those of NSO scientists. Scheduled maintenance (including instrument tests, engineering, and equipment changes) accounted for 3.0% of total allotted telescope hours.

Total "downtime" (hours lost to weather and equipment problems) for NSO telescopes was 33.8%. Almost all of these lost observing hours were due to bad weather (27.4%), with 6.5% lost to equipment problems.



NSO TELESCOPES Percent Distribution of Telescope Hours (Scheduled vs. Downtime) 01 October 2008 - 30 September 2009									
% Hours Used By: % Hours Lost To: % Hrs. Lost To:									
Telescope	Hours Scheduled	Visitors ^a	Staff	Weather	Equipment	Scheduled Maintenance			
Dunn Solar Telescope/SP	3,620.0	34.2%	18.8%	33.2%	3.4%	10.4%			
McMath-Pierce*	4,315.0	30.9%	44.8%	18.2%	6.1%	0.0%			
KP SOLIS Tower ^{a,b}	2,910.0	61.1%	2.4%	29.5%	7.0%	0.0%			
FTS Lab*	507.0	70.2%	0.0%	3.0%	26.8%	0.0%			
Evans Solar Facility	1,060.0	42.1%	0.0%	50.6%	7.4%	0.0%			
Hilltop Dome									
All Telescopes	All Telescopes 12,412.0 41.5% 21.6% 27.3% 6.5% 3.0%								

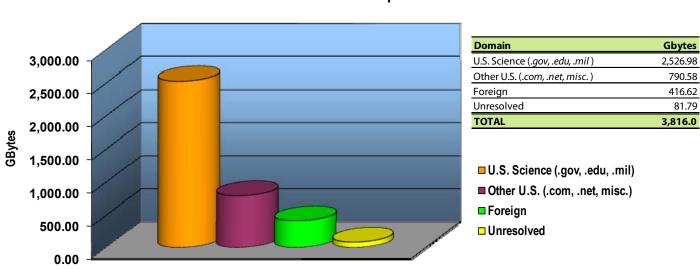
^aIncludes synoptic programs for which all data are made available immediately to the public and scientific community at large.

^b*Kitt Peak SOLIS Tower (KPST); formerly the Kitt Peak Vacuum Telescope (KPVT).*

*Totals include both day and night hours. (All others are day only.)

FY 2009 USER STATISTICS – ARCHIVES & DATA BASES

All statistics *exclude* the use of NSO archives and data bases from within the NSO Local Area Network in Tucson and at Sac Peak, and from NOAO as a whole.



DATA (Gbytes) DOWNLOADED FROM NSO FTP & WWW SITES 01 October 2008 - 30 September 2009

PRODUCT DISTRIBUTION BY DOWNLOADED GBYTES
01 October 2008 - 30 September 2009

Site	Product Type	Gbytes	%
Т	GONG Helioseismology	2,243.41	60.4%
Т	GONG (Magnetograms, spectra, time series, frequencies)	280.45	7.5%
SP	Realtime Images and Movies (OSPAN, Other)	408.71	11.0%
SP	SMEI Experiment & Data Pages	222.93	6.0%
SP & T	Other	163.75	4.4%
Т	SOLIS/VSM	146.05	3.9%
SP	General Information	60.27	1.6%
Т	KPVT (magnetograms, synoptic maps, helium images)	59.19	1.6%
SP	Staff Pages	52.84	1.4%
SP	Press Releases	32.20	0.9%
SP	Adaptive Optics Pages	9.08	0.2%
SP	Corona Maps & Other Images	8.26	0.2%
SP	Telescope Home Pages	8.26	0.2%
SP	Icon & Background Images	6.61	0.2%
SP	OSPAN Project Pages	4.95	0.1%
Т	FTS (Spectral atlases, general archive)	4.66	0.1%
SP	Public Relations	4.13	0.1%
Т	Evans/SP Spectroheliograms (Hα, Calcium K images)	0.01	0.0%
TOTAL		3,715.76	100.0%

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APPENDIX B: ORGANIZATIONAL PARTNERSHIPS

B1. Community Partnerships and NSO Leadership Role

Through its operation of the majority of U.S. ground-based solar facilities and its ongoing synoptic programs, NSO is clearly important to the solar community. In turn, NSO must work closely with the solar community and provide leadership to strengthen solar research, renew solar facilities and to develop the next generation of solar instrumentation. Some past examples of NSO meeting this responsibility include development of GONG and enhancement of the GONG network; development of solar adaptive optics; development of infrared observing capabilities in collaboration with the University of Hawai'i, California State University-Northridge, and NASA; and participation in the development of the advanced Stokes polarimeter and SPINOR in collaboration with HAO. Table B.1 lists several ongoing joint projects and development efforts.

Table B.1 Joint Development Efforts					
Telescope/Instrument/Project	Collaborators				
Advanced Technology Solar Telescope (ATST)	HAO, U. Hawai'i, U. Chicago, NJIT, Montana State U., Princeton U., Harvard/Smithsonian, UC-San Diego, UCLA, U. Colorado, NASA/GSFC, NASA/MSFC, Caltech, Michigan State U., U. Rochester, Stanford U., Lockheed- Martin, Southwest Research Institute, NorthWest Research Associates, California State U. Northridge				
Adaptive Optics	NJIT, Kiepenheuer Institute, AFRL				
Diffraction-Limited Spectro-Polarimeter ((DLSP)	HAO				
Spectro-Polarimeter for Infrared & Optical Regions (SPINOR)	HAO				
Rapid Oscillations in the Solar Atmosphere (ROSA) Instrument	Queen's University, Belfast				
Narrowband Filters and Polarimeters	Arcetri Observatory, U. Alabama, Kiepenheuer Inst.				
Synoptic Solar Measurements	USAF, NASA				
Fourier Transform Spectrometer	NASA, NSF/CHEM				
IR Spectrograph and Cameras	U. Hawai'i, California State U. Northridge				
Advanced Image Slicer & Integral Field Unit	California State U. Northridge				
Virtual Solar Observatory	NASA, Stanford, Harvard-Smithsonian Center for Astrophysics, Southwest Research Institute				
H-alpha Imaging System (GONG)	Air Force Weather Agency (AFWA)/AFRL				

NSO sponsored several community workshops and forged an alliance of 22 institutions to develop a proposal for the design of the ATST and its instrumentation. NSO worked closely with this group in leading the successful completion of the design and transition to construction of the telescope. Beginning in 2009, the ATST project held a series of workshops on ATST science operations to provide guidance for developing a sound plan for exploiting the full potential of the ATST.

B2. Operational Partnerships

NSO's strategic planning embraces the interdisciplinary nature and dual objectives of solar physics in that it is both basic science and applied research. Likewise, NSO's relationships to its users reflect the diversity and richness of the communities they represent—solar and stellar astronomy, space plasma physics, solar-terrestrial relationships, space weather prediction, terrestrial atmospheric chemistry, and more. Table B.2 is a summary of the current partnerships that provide operational support.

NSO's long-standing relationship with the U.S. Air Force space science group will continue into the ATST era. The Air Force Research Laboratory (AFRL) and its Office of Scientific Research (AFOSR) have indicated a desire to keep their basic solar research program colocated with NSO. They are contributing to the ATST project through their mirror coating chamber and are looking for ways to support ATST detector development. Currently, NSO is vigorously pursuing other partnerships. It has had discussions with many organizations and has received letters of intent from several institutions to support ATST construction. These include organizations in Germany; the United Kingdom; a consortium of the Netherlands, Sweden, and Norway; and the U.S. Air Force. Other potential partnerships include Italy, Japan, Spain, and Canada. Scientists from Italy, Japan, and Spain are currently involved on the ATST Science Working Group. NSO has formed a close working relationship with the University of Hawai'i for ATST operations and expects other partners to have some involvement in operations as well.

Table B-2. Current NSO Partnerships				
Partner	Program			
Air Force Research Laboratory	Solar Activity Research at NSO/SP; Telescope Operations; Adaptive Optics; Instrument Development; 4 Scientists Stationed at NSO/SP; Daily Coronal Emission Line Measurements; H-alpha Imaging System (GONG); Provides Operational Funding: \$400K-Base and Various Amounts for Instrument Development.			
NASA	 -Funding for SOLIS Science Goals: Postdoctoral Research Associates (1.25 FTE); Instrument/Observing Specialist (0.5 FTE). -McMath-Pierce: Support for Operation of the FTS (1.0 FTE); Upper Atmospheric Research; Solar-Stellar Research; Planetary Research. -Dunn: Support for a Research Fellow for HINODE mission support (coordinated observations, science planning, mission operations, data analysis) (via Lockheed-Martin sub-award). -GONG: 3.0 FTE Scientific Support; SDO/HMI Pipeline Development Support (0.7 FTE). -Funding for 1 Postdoctoral Research Associate in Astrobiology (0.5 FTE) -Virtual Solar Observatory Development Support (1.0 FTE). -Development of VSM advanced flux estimate map for next general model of the corona and solar wind (via SAIC sub-award). 			

GONG is actively seeking operational partnerships with members of the space environment community, including international partnerships for site operations and data processing. The Air Force has provided GONG with funds to add an H-alpha capability in anticipation of helping to fund GONG operations.

APPENDIX C: PUBLICATIONS (October 2008 through September 2009)

Author—NSO Staff <u>Author</u>—REU *Author*—RET <u>Author</u>—Grad Student <u>Author</u>—Non-REU Undergrad

The following is a partial list of papers published during FY 2009 by NSO staff, as well as papers resulting from the use of NSO facilities.

Refereed Publications

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APPENDIX D: MILESTONES FY 2010

This section describes the major project milestones for 2010.

D1. 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:

- Complete establishment of the Project Management Control System (PMCS).
- Establish vendor construction contracts for the major sub-assemblies (enclosure, telescope mount assembly, M1 blank, phase-2 Architecture and Engineering (A&E), etc.) as approval and funds become available.
- Obtain the conservation district use permit for construction on Haleakalā
- Complete the Special User Permit for using the Haleakalā National Park Road.

D2. Solar Adaptive Optics

- Continue MCAO development at the DST
- Develop the large format AO system for BBSO's 1.5m as a proof of concept for ATST
- Refine and implement stable and efficient MCAO control algorithms.
- Find optimum positions for the MCAO deformable mirrors.

D3. 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 2010 include:

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

D4. 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.
- Continue to provide VSM vector data online to the solar community and make comparisons with data products from other instruments while evaluating various inversion techniques.
- Install Sarnoff cameras and update analysis software to process new data format.

D4. SOLIS (cont.)

- Initiate SOLIS fast-scan observations of regions likely to flare, and archive new polarimetric data products from fast-scans.
- Develop extinction monitor data reduction algorithms and install instrument to monitor atmospheric line-of-sight conditions.
- Incorporate ISS data reduction into the SOLIS pipeline.
- Install monitor to record localized seeing conditions in the VSM line of sight.
- Complete development of guider for VSM and FDP instruments.
- Integrate FDP onto the mount at the SOLIS tower.
- Isolate changes in the vector photospheric field parameters before and after flare events as observed in the fast-scan observations.
- Integrate VSM vector photospheric and STEREO data to calculate and compare energy budgets for coronal fields and CME's.
- Purchase and begin testing the modulator from Meadowlark.

D5. Kitt Peak SOLIS Tower (KPST) Clamshell Repair and Improvements (ARRA Funded Project)

- Obtain contract bids.
- Repair hydraulic cylinders.
- Install hydraulic oil compensator system to account for uneven piston wear over time.
- Install hard stops to take load off cylinders when clamshell assembly is open.

D6. GONG

- Continue to develop local helioseismology methods, implement routine data production, and add new products to the archive. Next on the list is routine time-distance processing.
- Continue to develop magnetic field products as requested by the solar physics and space weather communities. Next on the list is an improved method to estimate polar fields.
- Continue development of space weather predictive tools using ring diagrams, the far-side signal, and the high-cadence magnetograms.
- Begin development of a distributed flare predictor system based on subsurface vorticity and located at the remote sites.
- 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. Efforts are focused on Udaipur and Learmonth.
- Complete the development of the US Air Force Weather Agency H α observing system for deployment in FY 2010.

D7. Virtual Solar Observatory

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

D8. NSO Array Camera (NAC)

- Develop dual-beam polarimetry feed optics for the NAC from 1000-2000 nm.
- Identify and purchase 3-5 micron polarization optics.
- Generalize sub-array readout on NAC.

D9. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

Significant progress on SPINOR development was achieved in FY 2009. Engineering runs on the DST were conducted and science data were obtained.

- 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.

D10. Facility IR Spectropolarimeter (FIRS)

This joint effort with University of Hawai'i is currently in the final implementation phase at the DST. The milestone for FY 2010 is:

• Implement storage area network (SAN) access and integrate FIRS into DST mechanisms via the common services server.

D11. 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 2009 and the primary milestones for FY 2010 include:

• Complete new motion control for DST mechanisms.

D12. Rapid Oscillations in the Solar Atmosphere (ROSA) Imaging System

- Implement data handling system.
- Release instrument to the community.

D13. McMath-Pierce Telescope Control System (TCS) Upgrade (ARRA Funded Project)

- Implement a 2D translating limb-guider system
 - Specify and design. Conceptual design review January 2010.
 - 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.

D14. Integrated Field Unit (IFU) for the McMath-Pierce

• Operate IFU as a user instrument.

D15. McMath-Pierce Glycol Cooling System Inspection and Repair (ARRA Funded Project)

- Obtain contractor bids for visual and non-evasive testing.
- Perform inspection, validate current documentation, and advise on repairs if needed.

D16. McMath-Pierce High-Speed, Large-Format Camera System (ARRA Funded Project)

- Obtain a visible light detector for the McMath-Pierce Telescope to complement the IR spectrographic program.
- Obtain a relatively fast computer with ample disk capacity to take full advantage of the camera.

D17. Establish NSO Headquarters

- Release call for letters of intention
- Hold site visits to NSO and to potential proposers
- Release call for proposals

APPENDIX E: STATUS OF FY 2009 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2009 Program Plan. (FY 2009 milestones appear in italics below.)

E1. Advanced Technology Solar Telescope

- Continue to develop funding partnerships for the construction phase. Discussions were held with potential partners, which included Japan, Italy, United Kingdom, Ireland, and Germany. Germany is working on an instrument, and the UK is seeking funds for cameras.
- Establish vendor design completion contracts as funds become available. A contract was awarded for the first phase of the Architectural and Engineering design work associated with the ATST site infrastructure, foundations and buildings.
- Hold final Systems Design reviews and Contract Package reviews in advance of construction. Project-conducted final Systems Design Reviews and Contract Package Reviews were held in November 2008.
- *Hold NSF conducted final design review, currently scheduled for early March 2009.* The project successfully completed the NSF conducted Final Design Review in May 2009.

E2. Solar Adaptive Optics

- Continue MCAO development at the DST In progress with collaboration between NSO and the Kiepenheuer Institut f
 ür Sonnenphysik.
- *Refine and implement stable and efficient MCAO control algorithms.* In progress.
- *Find optimum positions for the MCAO deformable mirrors.* In progress.

E3. 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.

E4. 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.

SOLIS continued to supply research grade data to the community. This included full-disk 630.2 photospheric and 854.2 chromospheric VSM magnetograms, subsequent generation of the Carrington rotation maps, as well as the calibrated spectral data and derived line parameters as observed by the ISS. In addition, a new SOLIS observing request form was generated and observations are now routinely taken in support of HINODE and Johns Hopkins University.

NATIONAL SOLAR OBSERVATORY

• 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.

Completed. VSM Milne-Eddington (ME) data inversions have been produced regularly and made available online to the solar community since April 1, 2009. NSO sponsored a vector comparison workshop and presented data for comparison with other polarimetric instruments and inversion techniques. Improvements to the current inversion technique are on-going.

• Install new cameras.

Installation of the new Sarnoff cameras was delayed until ME inversions could be routinely produced and the few remaining hardware issues that appeared during testing could be addressed. All hardware issues are now resolved and the cameras have undergone extensive testing with the observing software. Camera replacement is scheduled for the first two weeks in December 2009

• Initiate SOLIS fast-scan observations of regions likely to flare and archive new polarimetric data products from fast-scans.

SOLIS has been tested in fast-scan mode and is preparing to support SDO observations. Computing hardware has been upgraded and the VSM can now process scan lines in near-real time. The data archival system has also been upgraded to support such observations. In addition, a California State University, Northridge (CSUN) observing proposal to run joint observations in support of HINODE over active regions is currently being considered.

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

In progress. Hardware is undergoing final alignment, however development of data analysis software has been delayed due to efforts to produce ME data products.

• Complete development of guider for VSM and FDP instruments.

In progress. Design has been finalized, interface boards fabricated and undergoing assembly, and a vendor has been contacted for programming the processing chip.

• Integrate FDP onto the mount at the SOLIS tower.

Completion of the FDP has been delayed until completion of the guider and development of software to analyze images.

• Upgrade machines: CentOS, Java and CORBA upgrades.

Computing hardware has been upgraded and now runs CentOS with a newer version of Java. Because the VSM now reliably processes scan lines in near-real time, the need to upgrade CORBA has shifted from a requirement to desirable only if problems arise in the future.

• Isolate changes in the vector photospheric field parameters before and after flare events as observed in the fast-scan observations.

Solar Cycle 24 has been slow to start with no opportunities to date to run fast-scan observations over active regions about to flare.

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

In progress. Quality of VSM photospheric data has been evaluated and determined to be of very high quality. The late start of Solar Cycle 24 has delayed work on calculating and comparing energy budgets for coronal fields and CMEs.

E5. GONG

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

The development of local helioseismology methods continues to be a major emphasis within GONG. Recent activity has focused mainly on the development of time-distance methods, in particular those that can address north-south meridional flows at deep depths. These flows are believed to be a major factor determining the characteristics of the solar activity cycle. S. Kholikov and J. Leibacher have been developing a method using "nearly-sectoral" modes with low values of m/ℓ that primarily travel in the north-south direction

- Continue to develop magnetic field products as requested by the solar physics and space weather communities.
 - 1. A new improved method of reducing the zero-point variations in magnetograms acquired by different sites has been developed and an automated system to routinely apply the method will be installed this year.
 - 2. A new data product has been developed and implemented to fill a request from the USAF Research Laboratory in Albuquerque. This product is a four-band image containing the 10-minute average and standard deviation of the magnetic field, the average intensity, and synoptic-map weights all remapped to a latitude-longitude grid. This product was requested by the AFRL Air Force Data Assimilative Photospheric flux Transport (ADAPT) project, which is setting up a data assimilation system to predict the surface magnetic field and solar wind.
 - 3. A new method to estimate the magnetic field at the solar poles is being developed. This will improve the ability to detect coronal holes.
- Continue development of space weather predictive tools using ring diagrams, the far-side signal, and the high-cadence magnetograms.
 - 1. Have quantified subsurface vorticity signal to identify "dangerous" active regions.
 - 2. Have demonstrated that vorticity increases 1-3 days prior to a flare and shown that it provides the best yet prediction for flare activity.
 - 3. Have improved the far-side measurements to reduce the noise level and provide a probability that a phase-shift signature is due to an active region.
- Complete porting of GONG production software to Linux.

Completed. We expect to retire the "tarat" machine (the last of the big Sun servers) this coming year.

- 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.
 - 1. Negotiating with an internet service provider in Udaipur to provide a direct link between Udaipur and Tucson without passing through Ahmedabad.
 - 2. Exploring the possibility of joining the USAF on an Telstra 45 Mbit link between Learmonth and Sydney
- Begin development of US Air Force Weather Agency Hα observing system for deployment in FY 2010. The prototype design review was passed in September 2009. All of the components have been received from the vendors. The production filters have an issue with image quality; a solution in the form of custom corrector plates is being developed. The software system is essentially up and running with images being routinely returned from the Tucson prototype in real time. Deployment is scheduled for late spring 2010.

E6. Virtual Solar Observatory

• Continue spatial search development.

There has been little progress on this task. All resources have been concentrated on setting up the SDO data access.

• Set up SDO data access.

This task is nearly complete. Remote Decision, Risk and Management Sciences (DRMS) systems have been installed and are working at NSO, NASA GSFC, and Harvard Smithsonian CfA. The system to monitor the location of data and provide efficient access is nearly complete.

• Improve catalog searches.

There has been little progress on this task. All resources have been concentrated on setting up the SDO data access.

• Implement usage reporting system.

There has been little progress on this task. All resources have been concentrated on setting up the SDO data access.

• Develop interfaces for C and Matlab.

There has been little progress on this task. All resources have been concentrated on setting up the SDO data access.

E7. NSO Array Camera (NAC)

- *Conduct sunspot observations with NAC 1000-2200 nm polarimeter.* Complete. Telescope polarization signal removal was successful.
- Generalize sub-array readout on NAC. In progress.
- Implement in-line software fix for single-read frame image corruption. Complete.
- *Identify and purchase 3-5 micron polarization optics.* In progress.

E8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- 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.
 Significant progress on SPINOR development was achieved in FY 2009. Engineering runs on the DST were conducted and science data were obtained.

E9. Facility IR Spectropolarimeter (FIRS)

- Implement SAN access and integrate FIRS into DST mechanisms via the common services server. In progress.
- *Conduct science runs.* Completed.

E9. Facility IR Spectropolarimeter (FIRS) (cont.)

- Develop operator's manual. Completed.
- Provide operator training.
 - Completed.
- *Release the instrument to the user community.* Completed.

E10. Dunn Solar Telescope Critical Hardware (System Upgrade)

The scope of this effort was limited to replacing the fault-prone CAMAC system. Good progress on this effort was made in FY 2009 and the primary milestones for FY 2010 include:

- Complete A2D/D2D development.
 Mostly completed.
- Complete new motion control for DST mechanisms. In progress.

E11. Rapid Oscillations in the Solar Atmosphere (ROSA) Imaging System

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

E12. 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.

E12. McMath-Pierce Telescope Control System (TCS) Upgrade (cont.)

- 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.

ARRA funds have been awarded to accomplish this upgrade in FY 2010.

E13. Planetary Adaptive Optics System for the McMath-Pierce Telescope

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

E14. Integrated Field Unit (IFU) for the McMath-Pierce Telescope

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

E15. Establish NSO Headquarters

- Release a request for letters of interest in the fall of 2009 if ATST construction is underway. Currently scheduled for Jan 2010 due to delay in Record of Decision on ATST EIS.
- Obtain AURA and NSF agreement on the process for selecting a headquarters site.
- AURA has iterated on the solicitation for HQ.
- Estimate costs of a headquarters for various potential locations.

Rough estimates were made. Detailed estimates will be made when we receive letters of intent.

APPENDIX F: NSO FY 2010 STAFFING SUMMARY

FY 2010 Staffing Schedule

(In Full-Time Equivalents)

	Director's Office	Sunspot	Tucson	ATST	GONG	SOLIS	Total
Scientists	1.00	4.00	1.10	3.00	7.25	2.60	18.95
Engineering/Science Staff	-	6.00	2.05	18.00	7.00	3.95	37.00
Administrative Staff	1.00	4.50	0.48	4.00	2.00	0.32	12.30
Technical Staff	-	8.50	1.70		4.00	3.30	17.50
Maintenance & Service Staff	-	9.00			-	-	9.00
Total Base Program	2.00	32.00	5.33	25.00	20.25	10.17	94.75
AF Supported Science Staff	-	4.00		-	-	-	4.00
AF Supported Technical Staff	-	1.00	0.50	-	-	-	1.50
Other NSF Projects (AO, FTS/CHEM)	-	-		-	-	-	0.00
Graduate Students	-	1.00	1.00	-	-	-	2.00
NASA Supported Science Staff	-	1.00	3.95	-	3.75	-	8.70
NASA Support Engineering Staff	-	-	1.50	-	-	-	1.50
NASA Supported Technical Staff	-	-	0.50	-	-	-	0.50
Emeritus Science Staff	-	0.50	1.00	-	-	-	1.50
Visiting Scientists	-	-		-	-	-	
Total Other Support	0.00	7.50	8.45	0.00	3.75	0.00	19.70
Total Working at NSO	2.00	39.50	13.78	25.00	24.00	10.17	114.45

APPENDIX G: SCIENTIFIC STAFF RESEARCH AND SERVICE

(*Grant-supported staff)

Olga Burtseva, Research Associate

Areas of Interest

Local Helioseismology, Solar Activity

Recent Research Results

Burtseva continued her study of variations of the lifetimes of high-degree solar p modes in the quiet and active Sun with the solar activity cycle. The lifetimes were computed from SOHO/MDI data in an area including active regions and quiet Sun using the time-distance technique. Measured lifetime increases when regions of high magnetic activity are avoided. Moreover, the lifetime computed in quiet regions also shows variations with the activity cycle. Analysis of magnetic fields in the analyzed regions showed that the elements of heightened magnetic activity in the quiet regions could cause the residual lifetime variations in the quiet area. The results are published in: Burtseva, O., Hill, F., Kholikov, S., and Chou, D.-Y., "Lifetimes of High-Degree p-Modes in the Quiet and Active Sun," 2009, *Solar Physics*, 258, 1.

Burtseva also continues to study the high-degree acoustic mode amplitudes and widths in quiet-Sun regions during different phases of the solar activity cycle and at different latitudes. This is carried out using the ring-diagram analysis technique applied to the GONG data from 2001 to 2009. The temporal variations of the magnetic field in the quiet Sun using MDI magnetograms are also analyzed. The widths of the acoustic waves in the quiet Sun clearly show solar-cycle related trend, while in the amplitudes the variations are not that obvious. The solar cycle trend in the parameters is more significant at lower latitudes, and not obvious at high latitudes. Magnetic field of the regions also shows some solar-cycle trends.

Future Research Plans

Burtseva plans to continue analyzing the amplitudes of high-degree solar *p*-modes and the magnetic field in the quiet and active Sun in an attempt to understand what causes solar-cycle related variations in the parameters.

*Michael Dulick, Scientist

Areas of Interest

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

<u>Research</u>

Dulick continues to use 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 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

Elmore modeled the polarization properties of individual optical elements for solar research telescopes and evaluated several techniques for inferring properties of these elements using calibration and solar observational data. These results were presented at the first European Association for Solar Telescopes/Advanced Technology Solar Telescope (EAST-ATST) Workshop in October 2009.

Future Research Plans

Elmore will work with prospective instrument developers to define and develop instrumentation for the ATST. He will apply his thorough understanding of telescope calibration at the Dunn Solar Telescope toward development of the telescope calibration plan for the ATST. He also plans to utilize existing instruments at NSO, such as 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 the 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

One surprising result of the survey by Giampapa et al. of the 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 (2006; *ApJ*, 651, 444) 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. In follow-up work just accepted for publication in *The Astrophysical Journal*, Giampapa and his co-author, Ansgar Reiners (Institut für Astrophysik, Göttingen, Germany), utilized the UVES instrument on the VLT to measure projected rotation velocities in high-activity sun-like stars in M67. Reiners and Giampapa found that these objects were indeed rotating more rapidly. Hence, their relatively high activity is a natural consequence of rapid rotation combined with the dynamo-driven relationship between rotation and activity in late-type stars. However, why such objects are rotating more rapidly than the Sun in a solar-age cluster is unclear.

Future Research Plans

Giampapa and collaborator Ansgar Reiners (University of Göttingen) are considering an expanded rotational velocity survey in M67 to explore the mass-dependence of rotational evolution in this cluster and to further examine the rotation-activity connection at solar-age. Expanding this work to other clusters spanning a range of ages is under active consideration. In other work, Giampapa and his collaborators, including NASA-funded postdoc William Sherry, continue to acquire data on the short-term and long-term photometric variability of 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. An initial investigation of line bisector variability will be pursued.

<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. He also attends and sometimes presents at AURA Board and various committee meetings as appropriate. Giampapa is the PI for SOLIS as well as the instrument scientist for the SOLIS Integrated Sunlight Spectrometer (ISS). Giampapa 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. He also is the chair of the NSO/Tucson/Kitt Peak Priorities Review Committee (PRC). Giampapa represents the NSO on the NOAO Facilities 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

Areas of Interest

Local Helioseismology (Seismic Imaging and Ring-Diagram Analysis)

Recent Research Results

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 identification of a solar cycle variation in the background of such maps. A statistical analysis of three years of far-side maps have rendered a relationship between the signal of an active region (AR) in the far-side map and the probability of it appearing at the front-side in the following days. These new findings are now used in the daily GONG far-side maps to automatically highlight candidates to AR's in the far-side of the Sun and assign them a confidence level. González Hernández is also involved in the GONG Ring Diagrams pipeline and has been researching the meridional flow temporal variation from standard ring analysis.

Future Research Plans

González Hernández is currently working on a new magnetic index that will account for the active regions on the far-side of the Sun to complement front-side magnetic proxies such as Ly-alpha and F_10 indexes. She expects to further improve the quality of the far-side seismic maps by using a more accurate model (Green's functions) that has been developed recently.

The extended solar minimum has provided precedented data to study the subsurface meridional circulation. González Hernández plans to extend her previous work on the extra component of the meridional circulation that has a "torsional like" behavior.

<u>Service</u>

González Hernández participated in the NSO 2009 Research Experiences for Teachers (RET) summer program as mentor to middle-school teacher Helena Freedlund. She advised Freedlund on a project involving the classification of active regions detected by the far-side seismic maps.

*Brian J. Harker-Lundberg, Research Associate

Areas of Interest

Stokes spectropolarimetry of the photosphere; Stokes inversion techniques for inferring vector magnetic fields; automated tracking and classification of sunspot and active region structure; parallel processing computational techniques for data reduction.

Recent Research Results

B. Harker-Lundberg joined the NSO scientific staff as a postdoctoral fellow in February 2009. A new Stokes inversion code, named GENESIS (GENEtic Stokes Inversion Strategy), is nearing completion. Based on a genetic algorithm optimization principle and parallelized using nVIDIA's CUDA GPU-computing architecture, it shows how drastic speedups can be achieved by exploiting the dataparallel nature of the problem. Recently, GENESIS results were compared to those from a modified version of the original HAO/ASP inversion code which is currently implemented in the SOLIS VSM data reduction pipeline. Initial comparisons show GENESIS is not plagued by several of the pitfalls of local, gradient-descent-like optimization algorithms (dependence on initialization, becoming trapped in local minima, etc.). A comparison between co-temporal observations by SOLIS and *Hinode* SOT-SP showed that GENESIS was more consistent with the field structure inferred by the *Hinode* team's own internal inversion routine. This work is currently in preparation for submission to *Solar Physics*.

Future Research Plans

Harker-Lundberg plans to continue developing the GENESIS code, which offers configuration options so that that it is applicable to data from many different instruments, spectral lines, fields-of-view, etc. This should aid in comparisons of vector magnetogram inversion results between different co-spatial and co-temporal observations. Using the vector magnetograms from GENESIS, he will be implementing active-region tracking and classification algorithms to search for flare-related changes in the vector magnetic fields of sunspots and active regions.

John W. Harvey, Astronomer

Areas of Interest

Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results

During FY 2009, J. Harvey worked mainly on SOLIS and GONG instrument development and maintenance. Essentially no time was available for research. In preparation for installation of new cameras in the SOLIS VSM, Harvey continued to develop a powerful new method for removing fringes caused by CCD etalon effects in monochromatic light. He designed the optical system allowing addition of H-alpha imaging capability to the GONG instruments and developed some new narrow-band filter testing techniques.

Future Research Plans

During FY 2010, 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 implementation of an H α observing capability for GONG. He does not expect any significant time to be available for research. He continues to work with groups at AFRL and Predictive Sciences that are attempting to put solar magnetic field measurement on a sound quantitative basis. Harvey hopes to be able to resume doing research after retirement.

<u>Service</u>

J. Harvey has had responsible instrumental and scientific roles in the GONG and SOLIS projects. With the presently unspecified organization and start time of the new combined synoptic program, it is not clear what his role may be. Harvey is a member of the NSO Scientific Personnel Committee. Harvey participated in planning for the next Japanese solar satellite. He was a member of a committee effort to install a new solar professor at ETH. That effort was politically doomed and failed. He subsequently served as external expert appointed by the Swiss Federal Government to critically review the solar facility at Locarno. Harvey will present invited lectures in Switzerland and Spain in April 2010.

Frank Hill, Senior Scientist

Areas of Interest

Helioseismology, Asteroseismology, Fluid Dynamics of the Solar Convection Z one, the Solar Activity Cycle, Virtual Observatories, Solar Magnetic Fields

Recent Research Results

Hill continues to perform research in helioseismology. Recent work with R. Komm and A. Reinard (Space Weather Prediction Center, Boulder) has shown that the subsurface vorticity increases one to three days before major flares occur, and may lead to a useful space weather predictive tool.

Working with R. Howe and others, Hill has been tracking the progress of an east-west zonal flow in the solar interior known as the torsional oscillation as it slowly migrates from the solar poles to the equator. The flow for the current activity cycle is taking 1.5 years longer to travel equatorward and, since the current minimum phase is also 1.5 years longer than usual, there is probably a link between the two phenomena. This work attracted a fair amount of media attention.

Working with S. Kholikov, J. Leibacher, and others, Hill has been developing ways to measure the deep meridional flow using time-distance analysis. Preliminary work suggests that there may be a two-cell structure to the meridional flow as a function of depth. However, since this would be a revolutionary change in our understanding of the fluid dynamics of the solar convection zone, much more work on the inversions needs to be performed before a definitive conclusion can be reached.

Hill has been investigating the peculiar distribution of power in the three-dimensional spectrum of surface magnetic field fluctuations. Working with K. Jain and S. Tripathy, Hill found that, while the five-minute oscillation signature can be seen in the magnetic field, it has a surprising anisotropic distribution in terms of the direction of propagation. One probable hypothesis is that active regions are influencing the waves as they pass through.

Future Research Plans

Hill will start development of a space-weather prediction system based on the subsurface vorticity. The first step will be to perform the ring-diagram analysis on single-site data with the goal of deploying an analysis system at the remote GONG sites. Hill also hopes 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 directing 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, GONG and SOLIS data on-line and accessible over the Internet. He continues to participate in the development of the Virtual Solar Observatory, which was released to the public in December 2004. Hill typically supervises several staff, currently eight scientists, one manager, and one programmer. He acquired funding from the US Air Force Weather Agency (AFWA) in 2009 to develop and install an Hα observing capability in the GONG network. He submits around four proposals a year for outside funding. This year, Hill participated in two major proposals to the MRI-R² opportunity, one for a two nodes of the Stellar Observations Network Group (SONG) project, and the other for a new SOLIS/VSM instrument. He organized a Vector Magnetic Field Comparison Group, which held its first meeting in Tucson in late October. He will take on the role of the Associate Director of the Synoptic Program in the near future, which will combine SOLIS and GONG.

Rachel Howe, Associate Scientist

<u>Areas of Interest</u>

Helioseismology, the Solar Activity Cycle, Peak Fitting

Recent Research Results

Work on the solar rotation, on solar-cycle changes over 14 years of medium-degree observations, and on local frequency variations from ring-diagram analysis, is ongoing and in preparation. In January 2009, Howe was an invited attendee and presenter at an international HELAS workshop in Birmingham, England on the subject of "The Acoustic Solar Cycle." Howe has recently published a short paper entitled "A Note on the Torsional Oscillation at Solar Minimum," which was the subject of a press release at the June 2009 SPD meeting and attracted some press and blog attention. 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 early 2010) and as such attended the HMI team meeting held in Stanford, CA in September 2009 and is involved in regular telecons with the Stanford team. Howe is also involved in the analysis of preliminary stellar oscillations data from the Kepler spacecraft.

Future Research Plans

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. Howe also maintains the layout for the GONG resources CD, of which many copies were distributed at the 2009 SPD meeting.

*Kiran Jain, Assistant Scientist

Areas of Interest

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

Recent Research Results

Jain investigated the variation of high-degree mode frequencies as a local response to the active regions in two different phases of the solar activity cycle. It is shown that the correlation between frequency shifts and the surface magnetic activity measured locally are significantly different during the two activity periods. Most interesting result is found during extended minimum phase of the solar cycle where frequencies started to show anti-correlation with decreasing magnetic activity.

Jain also investigated the variation in the mode parameters obtained from time series of length 9, 36, 72 and 108 days to understand the changes occurring on different time-scales. The regression analysis between frequency shifts and activity proxies indicates that the correlation and slopes are correlated and both increase in going from time series of 9 to 108 days. It is found that the energy of the mode is anti-correlated with solar activity while the rate at which the energy is supplied remains constant over the solar cycle.

Future Research Plans

Jain will continue to investigate the effect of the choice of observables on helioseismic mode parameters and subsurface flows using simultaneous data sets. In particular, Jain plans to study the origin of acoustic signals in GONG magnetograms.

In addition, Jain will study the flow fields beneath sunspots that rotate around their vertical axis, generally classified as rotating sunspots. It is suggested that the origin of rotational motion is mainly due to the shear and twist in magnetic field lines or vice versa. It is also proposed that the magnetic twist may result from large-scale flows in the solar convection zone and the photosphere or in subphotospheric layers. Jain will apply the technique of ring-diagrams to investigate how flow fields change with depth.

Jain will also continue to study the influence of magnetic activity on varying oscillation frequencies, both locally and globally.

<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

Recent Research Results

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

The main focus of the pipeline is deep meridional flow measurements. A recent approach in this field is averaging huge amount of measurements over a long time period (1995-2009) to obtain depth profile of meridional flow. Preliminary results show very precise profile for deep layers of the Sun (down to tachocline region). Also, these last measurements will be used to investigate an evidence of return flow (equatorward) at the base of convective zone.

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*. Kholikov is a member of the Kepler Asteroseismic Science Consortium working group.

Future Research Plans

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

Recent Research Results

Keil's research took a back seat to developing an operations plan for the ATST, preparing for the ATST final design review, working on the new cooperative agreement, and preparing for the transition from ATST design and development to ATST construction. He continued to analyze phase and coherence spectra for waves propagating in the corona and comparing the Sac Peak Ca II K-line data with the new SOLIS data, looking for properties of the solar minimum and signs of the rise phase of the new solar

cycle. He was also involved in the working group to compare vector magnetograms from various instruments.

Future Research Plans

Keil is leading efforts to develop the Advanced Technology Solar Telescope. Time permitting, he plans to conduct observations of 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 magnetic field. As part of this effort, an agreement was established between NSO, HAO and the University of Hawai'i to relocate the Coronal One Shot to Mauna Loa, 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 provides input to the current astronomy and astrophysics decadal survey on both science objects and the ATST project.

*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.

Service

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

Areas of Interest

Helioseismology, Atmospheric Dynamics, Asteroseismology

Recent Research Results

Leibacher's recent work has focused on various aspects of helioseismic time-series analyses, including 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 recently launched K epler mission. 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 is 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 a number of undergraduate and graduate students all using GONG data, has been the external examiner on and member of a number of PhD juries recently. 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). He is editor of the journal *Solar Physics*.

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 Kitt Peak Vacuum Telescope (KPVT) showed a cyclic oscillation of the sunspot umbral intensity during the solar cycle from 1993 – 2003, where sunspots were darker on average during solar maximum and brighter during solar minimum. This agreed with infrared spectroscopic studies taken during the past seven years. Results were published in 2007. The velocity, line-depth and line-width KPVT data have been examined and reveal the same cyclic variation in over 8,000 sunspots, including a new small average radius variation. Recently, the NSO Array Camera (NAC) polarization optics obtained full Stokes profiles at 1083 nm and successfully removed the telescope and AO system polarization contamination from the data; line profiles will now be inverted using modern codes from the community.

Future Research Plans

Penn is currently involved in vector magnetic field observations using the 1083 and 1565 nm infrared lines and with imaging and spectroscopy at wavelengths from 4000-4700 nm from the McMath-Pierce telescope.

<u>Service</u>

Penn has recently completed a new polarimeter for use from 1000-2500 nm with the NAC; with successful removal of telescope polarization signatures, the NAC line profiles are ready to be inverted to derive solar magnetic vector fields. New work will include the development of a dual-beam polarization optical system to simultaneously measure orthogonal polarizations to remove atmospheric polarization cross-talk. At longer infrared wavelengths, successful imaging experiments have been done at 4700 nm, and new filters are being ordered for more work there. A polarimeter to operate in the 3000-5000 nm wavelength range is still being explored. Penn is involved with the ATST development, particularly the IR and coronal instrumentation for the ATST (Cryo-NIRSP and NIRSP-C) and with a group providing scientific feedback to the ATST software development group. Penn is advising a graduate student from the University of Arizona on a project exploring the KPVT spectroscopic data archive and also with

making new vector magnetic field measurements using the He 1083 nm spectral line, and inversion code (HAZEL) provided to the international community by the IAC (Spanish) group. 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/RET program.

*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. This work continues. Besides work on magnetic tilt angles mentioned under "Service", he has studied GONG one-minute magnetogram data sets for 77 flares and is writing a paper summarizing the field and flux changes and their physical implications. Recently, the estimated forces derived from this work contributed to explaining a seismic wave observed by colleagues on December 6, 2006. Petrie is also involved in the Whole Heliospheric Interval observing and modeling campaign (*http://ihy2007.org/WHI/*). He is developing nonlinear force-free models of the active fields of WHI with colleagues, and potential field models of the global corona for comparison with various observations. A topical issue of the journal *Solar Physics* will contain this work.

<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 2 NSO REU students during the summers of 2008 and 2009 to study and compare the magnetic field tilt angles in the photosphere and chromosphere. Some of this work has appeared in the Astrpophysical Journal. Petrie sat on NASA proposal review panels in 2006 and 2009.

Alexei A. Pevtsov, Associate Astronomer

Areas of Interest

Solar Magnetic Fields: Topology, Evolution, Helicity; Corona: Coronal Heating, X-ray Bright Points, Coronal Holes; Sunspots: Topology, Evolution, Evershed Flow, Helicity, Penumbral Fine Structure, Vector Polarimetry; Space Weather: Solar Drivers; Chromosphere: Filaments and Prominences, Moreton Waves.

Recent Research Results

Pevtsov worked with researchers from several US and international institutions on helicity of solar magnetic fields, solar cycle variations of coronal bright points, and evolution of coronal holes, and role of CMEs in driving chromospheric Moreton waves.

Using SOHO/MDI photospheric magnetic field measurements that cover most of solar cycle 23 (1996-2005), we calculate the total relative magnetic helicity injected into the solar atmosphere, and eventually shed into the heliosphere, over the cycle 23. Large active regions dominate the helicity injection process with $\sim 5.7 \times 10^{45}$ Mx² of total injected helicity. Peculiar active-region plasma flows account for $\sim 80\%$ of this helicity; the remaining $\sim 20\%$ is due to solar differential rotation. We find that helicity injection is well-balanced between two hemispheres: the net helicity injected is <1% of the above output. The typical helicity per active-region CME ranges between $(1.8-7) \times 10^{42}$ Mx² depending on the CME velocity. Although no significant net helicity exists over both solar hemispheres, we recover the well-known hemispheric helicity preference, which is significantly enhanced by the solar differential rotation. We also find that helicity injection in the solar atmosphere is an inherently disorganized, impulsive, and aperiodic process.

We study the evolution of magnetic fields and coronal structure associated with a coronal hole over several solar rotations. We found that this coronal hole has originated at the polar hole in one hemisphere, extended to equatorial region, got disconnected and transported across the equator to polar region of opposite hemisphere. During this evolution, we found significant variations in flux and area of CH, which suggests that although morphologically it appears as the same coronal hole, its photospheric/magnetic footprint is constantly changing. The latter implies that CHs are not a deep-rooted phenomena. Travel "path" of the CH does not appear to be random. Analysis of EIT images suggests that CH avoids areas of closed magnetic fields, and its path follows the large-scale boundaries between separate flux systems.

We use an automatic routine to identify coronal bright points (CBPs) and examine the variation of total number of CBPs in the course of solar cycle 23. Unlike some other recent studies, we do find a modest (~30%) decrease in the number of CBPs associated with maximum of sunspot activity. Using maximum brightness of CBPs as a criterion, we separate them on two categories: dim CBPs, associated with areas of quiet Sun, and bright CBPs, associated with active Sun. We find that number of dim coronal bright points decreases at the maximum of sunspot cycle, while the number of bright CBPs increases. The latitudinal distributions suggest that dim CBPs are distributed uniformly over the solar disk. Active-Sun CBPs exhibit a well-defined two-hump latitudinal profile suggestive of enhanced production of this type of CBPs in sunspot activity belts. Finally, we investigate a relative role of two mechanisms in cycle variations of CBP number, and conclude that change in the fraction of solar surface occupied by quiet Sun magnetic field is the primary cause with the visibility effect playing a secondary role.

Future Research Plans

Pevtsov plans to continue his studies of magnetic and current helicities on the Sun, coronal bright points, chromospheric filaments, and coronal holes. He also plans to study properties of magnetic bipoles associated with coronal bright points, continue analyzing historic records of Ca II K observations, and participate in research on coronal mass ejections and Moreton waves.

<u>Service</u>

Until January 31, 2009, Pevtsov served 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, and TRACE. After his return to NSO, he reviewed proposals for several NASA and NSF programs and served as a reviewer for four professional publications, *Astrophysical Journal, Solar Physics, Journal of Astronomy and Astrophysics, and Advances in Space Research*. A. Pevtsov supervises the NSO/SP technical librarian, and is a member of Time Allocation Committee for NSO/SP. He mentored one student participant of the 2009 NSF/NSO Summer Research Experience for Undergraduates (REU). Pevtsov teaches two on-line undergraduate classes at New Mexico State University. He serves on the Users Committee for HAO's Mauna Loa Solar Observatory, and is a member of the AAS Solar Physics Division (SPD) Committee.

Thomas R. Rimmele, Astronomer

Areas of Interest

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

Recent Research Results

During the past few 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 chromosphere 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 postdocs at NSO and the 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 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 Haleakala. 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.

Recent Research Results

W. Sherry used main sequence fitting to determine the distance to the σ Ori cluster. The σ Ori cluster is an important cluster because it is a young, three-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.

Working with NOAO's Steve Howel, W. Sherry used speckle observations of two dozen KEPLER extrasolar planet candidate to show that several of these candidates were likely false positives, background eclipsing binaries blended with a foreground star to mimic a transiting "hot Jupiter".

Future Research Plans

W. Sherry plans to continue the photometric monitoring of solar type members of the Pleiades with Mark Giampapa. They are currently extending their work using a new instrument that allows them to sample the light curves with much higher cadence (10 times per hour versus once per day) and greater precision. In 2010, 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 was awarded six half nights on the KPNO 4-m telescope with the MOSAIC camera in the winter of 2009. He was awarded three nights in December 2009 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 was launched 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.

*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.

Recent Research Results

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, participated in the development of algorithms for reduction of Ca K and Ca H parameters and time series. She has been working on calibration issues with the SOLIS vector spectromagnetograph (VSM), specifically removing influences of strong magnetic fields from the vector flats, removing modulation fringes from the Stokes polarizations, and processing the vector calibration images. The fringe removal is accomplished by fitting the observed fringes to a two-dimensional fringe model and then removing the fringes analytically. Although this leaves some residual fringes, these are removed by a temporal detrending method developed by J. Harvey. Most recently, she has been working on Milne-Eddington inversions of VSM spectra.

Future Research Plans

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. Further work on the Milne-Eddington inversions is planned. This includes characterizing the minimization surface of the fit parameters, optimizing the initial guesses and possibly convergence criteria.

<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

Areas of Interest

Global Helioseismology: Frequencies and Mode Parameters from Time Series of Short and Long-Periods, Local-helioseismology: Local analysis of Active, Flaring and CME Source Locations, Analysis of Simulated Helioseismology data, Solar Activity Cycle.

Recent Research Results

S. Tripathy has investigated the behavior of the intermediate degree mode frequencies of the Sun during the extended minimum phase of the solar cycle to explore the conditions in the solar interior. Using contemporaneous helioseismic data from GONG and MDI, he found that the changes in mean oscillation frequencies are significantly higher than the changes in solar activity as measured by different activity proxies. The study also detected a seismic minimum in MDI frequencies during July-August, 2008, indicating the onset of the new cycle 24. He also noticed a surprising anti-correlation between frequency shifts and activity proxies during the current minimum in contrast to the behavior during the minimum in 1996/1997. Since no anti-correlation has been detected in earlier solar cycles, he concludes that the current minimum is unusual.

S. Tripathy has investigated the variation of high-degree mode frequencies as a local response to the active regions in two different phases of the solar activity cycle. He reports that the correlation between frequency shifts and the surface magnetic activity measured locally is significantly different during the two activity periods.

S. Tripathy has determined the characteristic properties of oscillation mode parameters by applying the ring-diagram technique to the solar active region NOAA 10486 during the long duration flare of October 28, 2003. By comparing the pre- and post-flare phases, he reports strong evidence of systematic variations in sub-surface flows, i.e. meridional and zonal components of velocity, kinetic helicity and vorticity.

Future Research Plans

S. Tripathy will continue to devote his time analyzing and comparing MDI (HMI) and GONG data both globally and locally and from time series of different lengths. Specifically, there are plans to study the effect of the magnetic field on the oscillation frequencies measured from ring-diagrams in order to comprehend and quantify the source of the frequency shifts. The focus would be to analyze the current minimum phase since it is unusually long. He will also continue to search for activity precursors in the flow fields using data from MDI (HMI), GONG, and SOLIS.

<u>Service</u>

S. Tripathy participated in NASA proposal peer reviews.

Alexandra Tritschler, Research Associate

Areas of Interest

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.

Recent Research Results

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.

Future Research Plans

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, is a member of the Sac Peak telescope allocation committee (TAC), and provides a significant amount of software and data-reduction support for IBIS. Tritschler 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

Recent Research Results

H. Uitenbroek continues to work on expanding and improving his multi-dimensional numerical radiative transfer code. The most recent additions include improvements to the numerical behavior in the presence of sharp temperature, density, and velocity gradients. There is a great need for techniques that can provide measurement of magnetic field strength in the solar chromosphere. Only a handful of spectral lines are sensitive to the field in these relatively poorly understood layers of the solar atmosphere. Among them are the Ca II infrared triplet lines, the sodium D lines, and the hydrogen H α line. Uitenbroek is performing forward modeling calculations in multi-dimensional simulations of solar magneto-convection to study the sensitivity of the Na I D lines and the Ca II infrared triplet lines to the chromospheric magnetic field. He is computing response functions, which provide a measure of the 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. It's possible that 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-theart 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 Observatory in Florence, Uitenbroek used observations of IBIS in the Ca II 854.2 nm line to investigate the nature of a bright filamentary structure near a sunspot umbra. They speculate that this feature may be the result of current dissipation induced by a horizontal discontinuity in the magnetic field which results from convection induced foot point motions.

With Marianne Faurobert and Catherine Grec of the University of Nice, Uitenbroek investigated the viability of the so called differential speckle imaging technique by applying this technique to spectra

computed from numerical three-dimensional MHD simulations, and determined that it is a viable method to observationally deduce the formation height of spectral lines relative to that of the continuum.

Future Research Plans

In the coming year, Uitenbroek plans to continue with the development of his radiative transfer code. It will be used to investigate the formation of chromospheric lines, including their polarization, in newly available MHD simulations that include the chromosphere and transition region. This will show how well the chromospheric thermodynamic conditions as well as the magnetic field can be recovered 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.

<u>Service</u>

Uitenbroek serves as the chair of the Telescope Allocation Committee at Sac Peak, and 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 New Mexico State University in Las Cruces. He 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 committee of Sarah Jaeggli at the University of Hawai'i. He is also member of the planning working group for the next Japanese solar satellite Solar C.

Friedrich Wöger, Assistant Scientist

Areas of Interest

Image Reconstruction, Adaptive Optics, Two-Dimensional Spectroscopy, and Spectropolarimetry, ATST Data Handling System

Recent Research Results

Wöger is involved in research of the solar dynamic magnetic chromosphere in collaboration with Sven Wedemeyer-Böhm (Institute for Theoretical Astrophysics, University of Oslo), Han Uitenbroek and Thomas Rimmele (NSO). He has pursued observations of 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 was the Ca II infrared line at 854.2 nm, for which a method to derive the magnetic field structure has been developed.

Recently, Wöger has been working on algorithms to compute the transfer function of Earth's turbulent atmosphere and the adaptive optics system directly from the data delivered by the adaptive optics system. This allows the ability to compute speckle reconstructed images at the telescope in near-real time, a significant step for instruments such as the Visual Broadband Imager (VBI).

Future Research Plans

Wöger is working with Jose Marino, Thomas Rimmele and Robert Upton on reconstruction schemes for use with the DST and, later, the ATST (multi-conjugate) adaptive optics systems. He continues to work on developing accurate models for atmospheric transfer functions.

<u>Service</u>

Wöger is in charge of the data handling at the DST, and is supervising the movement of the standard data products from tapes to hard drives. He is also involved in the ATST Data Handling System development as the ATST Data Scientist, with the responsibility of setting the requirements for the system.

APPENDIX H: ACRONYM GLOSSARY

A&E	Architecture and Engineering
ADAPT	Air Force Data Assimilative Photospheric flux Transport
AFRL	Air Force Research Laboratory
AFWA	Air Force Weather Agency
AISES	American Indian Science and Engineering Society
aO	Active Optics
a0 A0	Adaptive Optics
ARRA	American Recovery and Reinvestment Act
AKKA ATI	
ATM	Advanced Technology Instrumentation (NSF)
	Atmospheric Sciences (Division of NSF)
ATRC	Advanced Technology Research Center (University of Hawai'i)
ATST	Advanced Technology Solar Telescope
AURA	Association of Universities for Research in Astronomy, Inc.
BBSO	Big Bear Solar Observatory
CD-ROM	Compact Disk – Read Only Memory
CfA	Center for Astrophysics (Harvard Smithsonian)
CfAO	Center for Adaptive Optics
CHU	Critical Hardware Upgrade
CLEA	Contemporary Laboratory Exercises in Astronomy
CMEs	Coronal Mass Ejections
CNC	Computer Numerical Controlled
CoDR	Conceptual Design Review
CoSEC	Collaborative Sun-Earth Connection
CR	Carrington Rotation
CSF	Common Services Framework
DA	Diversity Advocate
D&D	Design & Development
DASL	Data and Activities for Solar Learning
DEIS	Draft Environmental Impact Statement
DHS	Data Handling System
DLSP	Diffraction-Limited Spectro-Polarimeter
DLT	Digital Linear Tape
DM	Deformable Mirror
DMAC	Data Management and Analysis Center (GONG)
DoD	Department of Defense
DRD	Design Requirements Document
DRMS	Decision, Risk and Management Sciences (NSF)
DST	Dunn Solar Telescope
EGSO	European Grid of Solar Observations
EIS	Environmental Impact Statement
EPO	Educational and Public Outreach
ESF	Evans Solar Facility
ETS	Engineering and Technical Services (NOAO)
FDP	Full-Disk Patrol (SOLIS)
FEIS	Final Environmental Impact Statement
FLC	Ferroelectric Liquid Crystal
FOV	Field of View

FTEs	Eull Time Equivalente
	Full Time Equivalents
FTS	Fourier Transform Spectrometer Fiscal Year
FY	
GB	Giga Bytes Clobal Oscillation Naturals Crown
GONG GSFC	Global Oscillation Network Group
	Goddard Space Flight Center (NASA)
HAO	High Altitude Observatory
HOAO	High Order Adaptive Optics
HR	Human Resources
IBIS	Interferometric BIdimensional Spectrometer (Arcetri Observatory)
ICD	Interface Control Document
ICS	Instrument Control System
IDL	Interactive Data Language
IfA	Institute for Astronomy (University of Hawai'i)
IHY	International Heliophysical Year Infrared
IR	
IRES	International Research Experience for Students (NSF)
ISOON	Improved Solar Observing Optical Network (now O-SPAN)
ISS	Integrated Sunlight Spectrometer (SOLIS)
IT&C	Integration, Testing, & Commissioning
KCE	KC Environmental (Maui)
KIS	Kiepenheuer Insti Kitt Back National Observatory
KPNO	Kitt Peak National Observatory
KPVT	Kitt Peak Vacuum Telescope
LAPLACE	Life and PLAnets Center (University of Arizona)
LRP	Long Range Plan
LTE	Local Thermodynamic Equilibrium
LWS MoMD	Living With a Star McMath-Pierce
McMP	
MCAO MCC	Multi-Conjugate Adaptive Optics
	Maui Community College Maui Economia Development Reard
MEDB	Maui Economic Development Board Magnetohydrodynamic
MHD	Magnetonydrodynamic Mauna Kea Infrared
MKIR MREFC	
MREFC	Major Research Equipment Facilities Construction (NSF)
NAC	Major Research Instrumentation (NSF) NSO Array Camera
NAC	NASA Astrobiology Institute
NAS	National Academy of Sciences
NAS	National Aeronautics and Space Administration
NCAR	National Center for Atmospheric Research
NDSC	Network for the Detection of Stratospheric Change
NHPA	National Historic Preservation Act
NIR	Near Infrared
NJIT	New Jersey Institute of Technology
NLFF	Non-Linear Force-Free
NLTE	Non-Local Thermodynamic Equilibrium
NOAA	National Oceanic and Atmospheric Administration
NOAA	National Optical Astronomy Observatory
NRC	National Research Council
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NGDD	National Cariate of Dlash Dhariate
NSBP	National Society of Black Physicists
NSHP	National Society of Hispanic Physicsts
NSF	National Science Foundation
NSF/AST	National Science Foundation, Division of Astronomical Sciences
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 Big Bear Solar Observatory)
OCD	Operations Concept Definition Document (ATST)
OCS	Observatory Control System
OMB O SDAN	Office of Management and Budget
O-SPAN	Optical Solar Patrol Network (formerly ISOON)
PAARE	Partnerships in Astronomy & Astrophysics Research & Education (NSF)
PAEO PCA	Public Affairs and Educational Outreach (NOAO)
	Principal Component Analysis Proliminary Design Payion
PDR	Preliminary Design Review
PI	Principal Investigator Project Monogement Control System
PMCS	Project Management Control System
PSPT	Precision Solar Photometric Telescope
QA/QC	Quality Assurance/Quality Control
QSA RASL	Quasi-Static Alignment Research in Active Solar Longitudes
RDSA	Reference Design Studies and Analyses
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RFP	Request for Proposal
RISE/PSPT	Radiative Inputs from Sun to Earth/Precision Solar Photometric Telescope
RMS	Root-Mean-Square
ROD	Record of Decision
ROSA	Rapid Oscillations in the Solar Atmosphere
SACNAS	Society for the Advancement of Chicanos an Native Americans in Science
SAN	Storage Area Network
SCB	Sequential Chromospheric Brightening
SCOPE	Southwest Consortium of Observatories for Public Education
SFC	Space Flight Center (NASA)
S&O	Support and Operations (ATST)
SOC	Solar Observatory Council (AURA)
SOHO	Solar and Heliospheric Observatory
SOI	Solar Oscillations Investigations (SOHO)
SOLIS	Synoptic Optical Long-term Investigations of the Sun
SONG	Stellar Oscillation Network Group
SOT	Solar Optical Telescope
SOW	Statement of Work
SPINOR	Spectro-Polarimeter for Infrared and Optical Regions
SPD	Solar Physics Division (AAS)
SRA	Summer Research Assistant
SRD	Science Requirements Document
SSP	Source Selection Plan (ATST)
SST	Swedish Solar Telescope
	1

SSWG SWG STEM STEP TAC TB TCS TLRBSE TMA	Site Survey Working Group (ATST) Science Working Group (ATST) Science, Technology, Engineering and Mathematics Summer Teacher Enrichment Program Telescope Time Allocation Committee Tera Bytes Telescope Control System Teacher Leaders in Research Based Science Education Telescope Mount Assembly
TRACE	Transition Region and Coronal Explorer
UA	University of Arizona
UH	University of Hawaii
UBF	Universal Birefringent Filter
UPS	Uninterruptible Power Supply
USAF	United States Air Force
USF&WS	U.S. Fish and Wildlife Service
VCCS	Virtual Camera Control System (Dunn Solar Telescope)
VSM	Vector Spectromagnetograph (SOLIS)
VSO	Virtual Solar Observatory
VTF	Visible Tunable Filter
WBS	Work Breakdown Structure
WCCS	Wavefront Correction Control System
WWW	World Wide Web