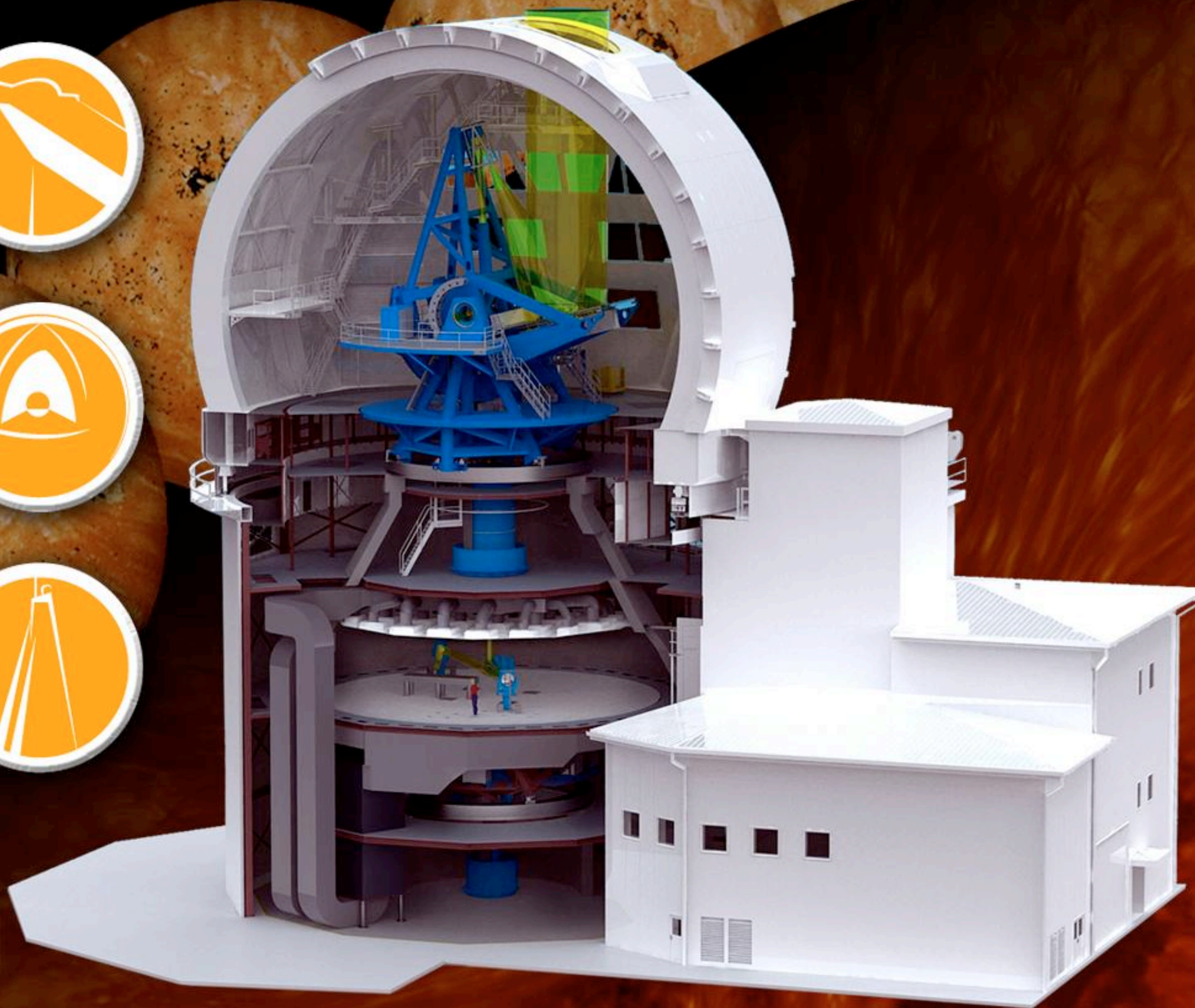

NATIONAL SOLAR OBSERVATORY

NSO

FY 2010 Annual Progress Report & FY 2011 Annual Program Plan

Submitted to the National Science Foundation under
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This report is also published on the NSO Web site: *http://www.nso.edu*

The National Solar Observatory is operated by the
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cooperative agreement with the National Science Foundation

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 (SOLIS and GONG) 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 2010 include:

- Start of ATST construction.
- Obtaining Air Force funds to support GONG operations
- Commissioning of the Spectro-Polarimeter for Infrared and Optical Regions (SPINOR) at the Dunn Solar Telescope (DST).
- Commissioning of the Integrated Field Unit (IFU) at the McMath-Pierce Solar Telescope (McMP).
- Launch of the quest for a new NSO headquarters.

A few of the major actions to advance solar physics that NSO will undertake in FY 2011 include:

- Continuing the construction of ATST 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.

- Completing the merger of SOLIS and GONG into a single synoptic program, allowing us to take advantages of synergisms in data and technical support.
- Collaborating on a large-format AO system with the Big Bear Solar Observatory for their New Solar Telescope (NST). This system also serves as a prototype for the even larger ATST AO system.

Figure 1 summarizes NSO's FY 2011 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 is implementing the construction plan, and contracts for the telescope mount assembly, enclosure, and primary mirror have been established. Bid packages for the mirror polishing, the M1 mount, M2 assembly and support structure will be released. Staffing positions for the project have been filled.

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 cameras and modulators have been updated to provide a more robust system. The FDP will be installed this fall completing the full suite of SOLIS instruments. A worldwide network of SOLIS instrumentation was one of the low-cost recommendations of the previous Decadal Survey. NSO will continue to explore possible 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. As a result, the Air Force will support GONG operations in FY2011 and we will pursue funding from other space weather agencies such as the National Oceanic and Atmospheric Administration (NOAA).

NSO's FY 2011 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 and the completion of SOLIS.

NSO 2011 Program

- **ATST**
  - **Obtain conservation district use permit (CDUA) for construction on Haleakalā**
  - **Begin mirror blank polishing**
  - **Work with enclosure and Telescope Mount Assembly (TMA) contractors**
  - **Conduct baseline review, and instrument preliminary design reviews (PDRs)**
  - **Begin site construction**
- **Dunn Solar Telescope (all ATST related activities)**
  - **Continue development of multi-conjugate adaptive optics**
  - **Test bed for ATST instrument development**
  - **Conduct scientific operations for the solar community**
- **McMath-Pierce Solar Telescope (all ATST related activities)**
  - **Enhance telescope control system (TCS) to exploit the NSO Array Camera (NAC) (1–5 microns) and thermal-IR**
  - **Conduct scientific operations for the solar community**
- **GONG**
  - **Continue streamlining operations**
  - **Complete Hα installations**
  - **Continue to seek additional funding partnership(s)**
  - **Incorporate into a synoptic network with SOLIS**
- **SOLIS**
  - **Operations**
  - **Install Full-Disk Patrol (FDP) and Utrecht S^5T**
  - **Incorporate data into Digital Library (DL) and Virtual Solar Observatory (VSO)**
  - **Incorporate into synoptic network with GONG**
- **Digital Library and Virtual Solar Observatory**
  - **Continue work on next release version; operation of NSO node**
  - **Continue strong collaboration with U.S. and European institutions**
  - **Start development of Data Center to incorporate ATST & SOLIS data**
- **NSO Directorate Site Development and Staff Consolidation**
  - **Begin selection process**
- **Education and Outreach and Broadening Participation**
  - **Train 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 continue to 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 magneto-hydrodynamics (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 has entered a 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 directorate location where we can consolidate our scientific staff. This Annual Progress Report and Program Plan discussion highlights the progress during execution of NSO's FY 2010 program and plans for FY 2011.

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 2011 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 2010 SCIENTIFIC RESEARCH AND DEVELOPMENT HIGHLIGHTS

2.1 Recovering the Line-of-Sight Magnetic Field in the Chromosphere

The chromosphere is the region in which the solar plasma goes from a high beta to low beta regime and hence forms an important link between the gas dominated photosphere and magnetically dominated corona. For this reason, knowledge of the chromospheric magnetic field topology and dynamics is of significant importance for the understanding of the solar atmosphere. Yet, these properties are poorly known due to limitations set by current observational techniques, in particular when gathering data of weak-field regions in the quiet Sun. In addition, the interpretation of chromospheric spectro-polarimetric data has proven to be difficult as many complicating effects have to be taken into account, such as non-local thermodynamic equilibrium (NLTE) conditions.

Friedrich Wöger, Sven Wedemeyer-Böhm (U. Oslo), Han Uitenbroek, and Thomas Rimmele have developed a method to derive the line-of-sight magnetic flux density from measurements in the chromospheric Ca II IR line at 854.2 nm. The method combines two well-understood techniques, the center-of-gravity and bisector methods, in a single hybrid technique. They first tested the technique by applying it to magnetostatic simulations of a flux tube (Figure 2.1-1). They then apply the method to observations with the Interferometric Bidimensional Spectrometer (IBIS) installed at the Dunn Solar Telescope to investigate the morphology of the lower chromosphere, with focus on the chromospheric counterparts to the underlying photospheric magnetic flux elements (Figure 2.1-2).

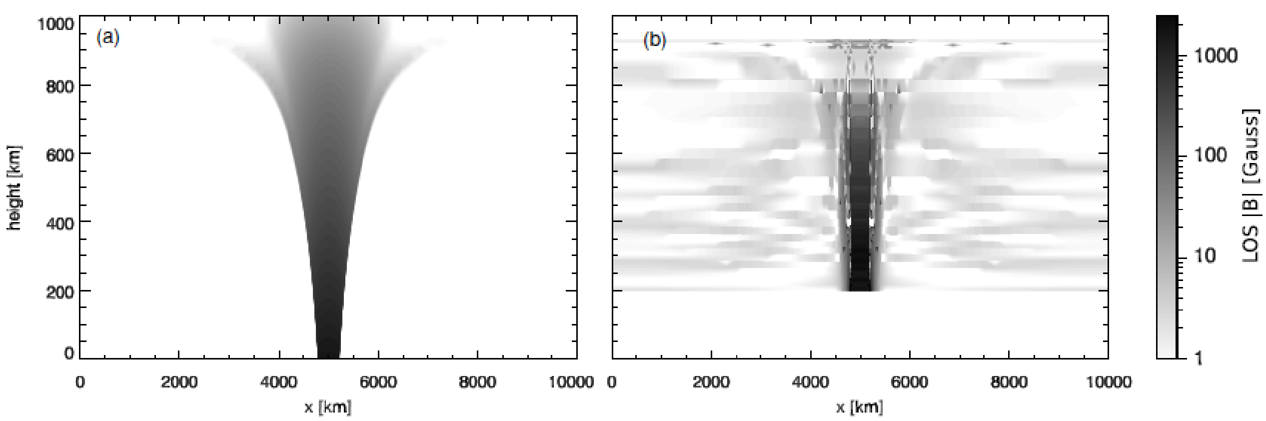


Figure 2.1-1. Result of the accuracy test of the proposed hybrid bisector-COG method. a) input model, and b) recovered flux density. The height scale in b) was derived using calculations of $\tau_\lambda = 1$. The gray scale encodes the magnetic flux density and is the same for both panels.

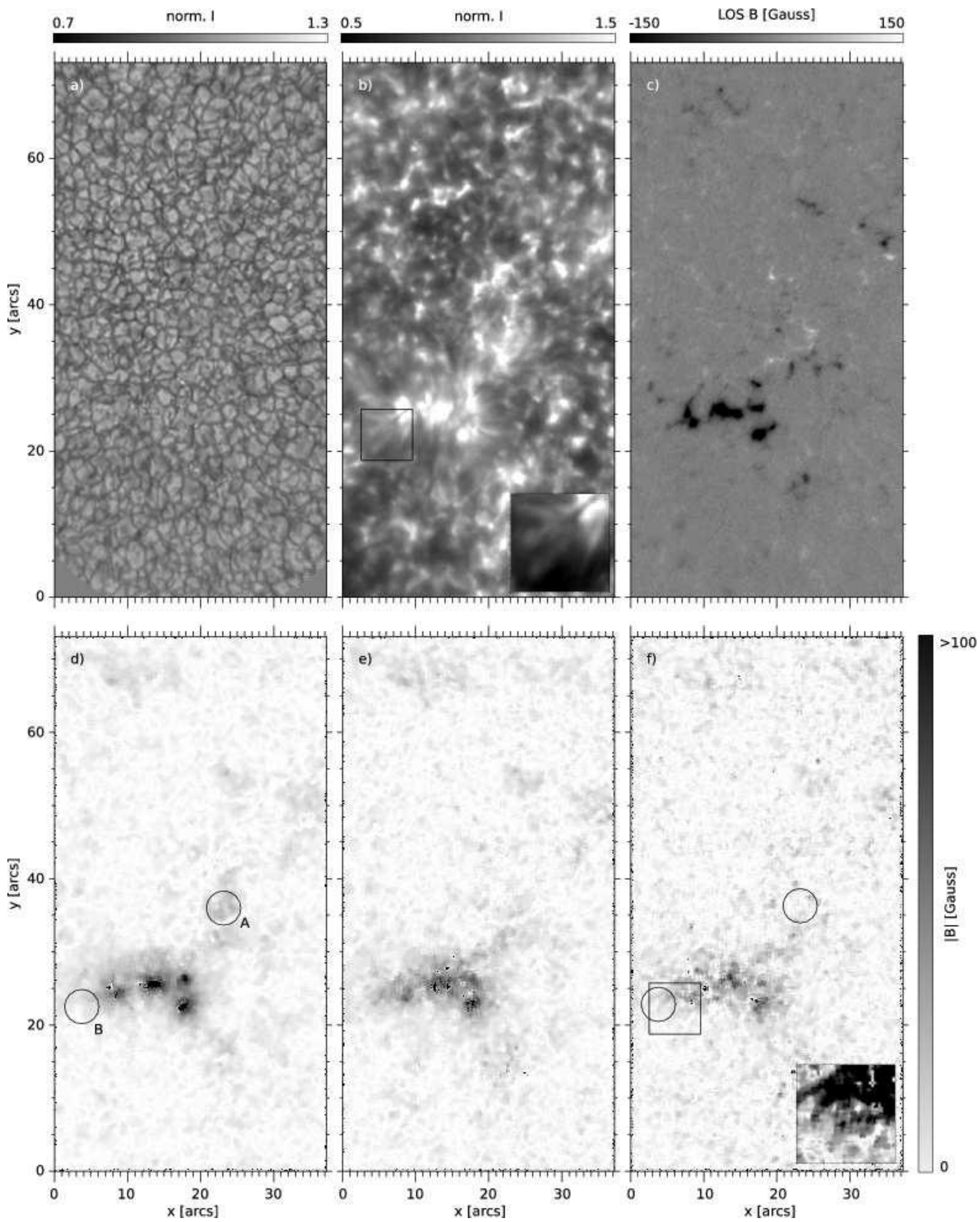


Figure 2.1-2. *Panel a) Continuum intensity around 852 nm; Panel b) Ca II IR (854.2 nm) line core intensity; Panel c) LOS magnetogram computed from Fe I (630.2 nm). Cuts through the recovered 3D topology of the magnetic flux density by applying the hybrid bisector-COG method to the Ca II IR line scan. Panel d) is at 32% of the local continuum intensity (photospheric); Panel e) at 20.2%; and Panel f) at 18.5% (chromospheric/"fluctospheric"). The subpanel in f) shows a contrast enhanced close-up of the fibrils marked by the box. At location A, a patch of magnetic flux along the line-of-sight seems to disappear with increasing height (also, see subpanel). Location B is an example for the appearance of a filament like structure with height.*

2.2 What Solar Oscillations Tell Us About the Solar Minimum

The delayed onset of solar cycle 24 and the prolonged period of minimal solar activity have invoked great interest in a variety of studies that might be useful to characterize the Sun in a quiet state. Studies based on the helioseismic data have provided conflicting estimates of the length of previous cycle and have shown that the present minimum is indeed the deepest in many aspects. Since acoustic modes spend most of the time in the outer layers of the solar interior, the intermediate- and high-degree modes can be useful in interpreting the conditions in the convection zone. In this context, K. Jain, S. C. Tripathy, O. Burtseva, I. González Hernández, F. Hill, R. Howe, S. Kholikov, R. Komm and J. Leibacher investigated the response of these modes to the period of minimum activity and compare the response with the previous one.

The availability of continuous helioseismic data for two consecutive solar minima has provided a unique opportunity to study the changes in the solar interior that might have led to the unusually long minimum of cycle 23. Jain et al. analyzed intermediate-degree mode frequencies in the 3 mHz band during the minimal solar activity in cycle 23 and show that the mode frequencies are significantly lower than those during the previous activity minimum. Their analysis does not show any signature of the beginning of cycle 24 till the end of 2008. In addition, the zonal and meridional flow patterns inferred from inverting frequencies also hint for a delayed onset of a new cycle. The estimates of travel time are higher than the previous minimum confirming the relatively weak solar activity during the current minimum.

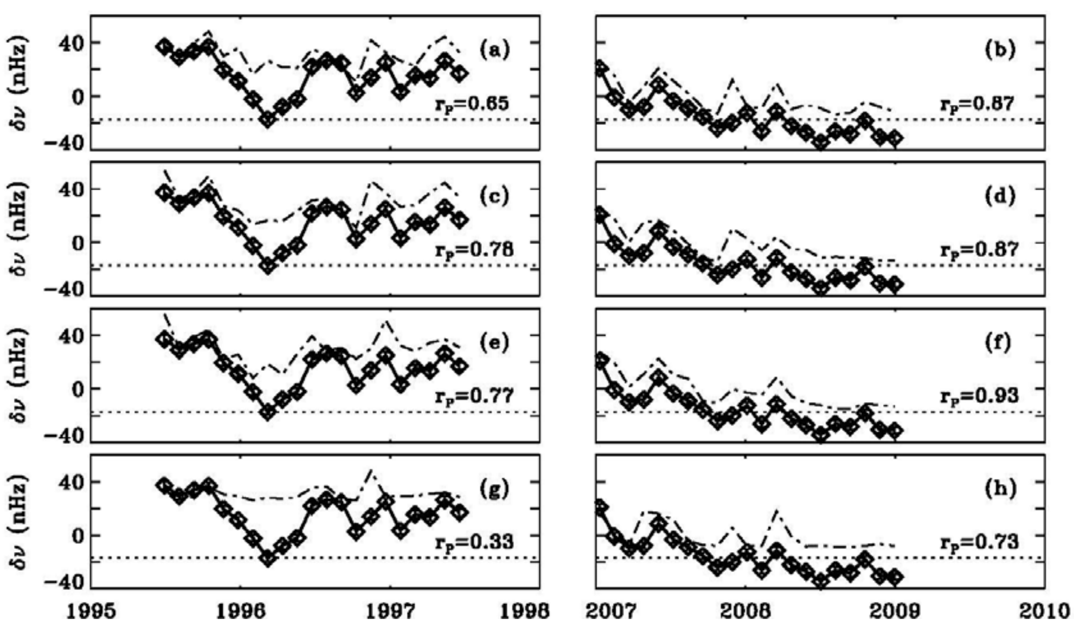


Figure 2.2-1. *Temporal evolution of the m-averaged frequency shifts (symbols) with scaled activity proxies (dashed-dot) during minima between cycles 22 and 23 (left), and 23 and 24 (right). The activity proxies used here are; (a-b) the international sunspot number, (c-d) the F10.7 cm radio flux, (e-f) the Mt. Wilson plage strength index, and (g-h) the Mt. Wilson sunspot index. Pearson's correlation coefficients (rP) between frequency shifts and solar activity are indicated in each panel. Dotted line represents the lowest frequency shift during the minimum between cycles 22 and 23.*

It is evident from Figure 2.2-1 that the frequencies are lower and the correlation coefficients are higher for all activity proxies during the current minimum as compared to the previous minimum. The best correlation is found for the proxy depicting the change in weak component of the magnetic field, represented here by the strength of plages (Figure 2.2-1 e-f). The other indices (sunspot number, radio flux and the strength of sunspots) have major contribution from the strong component. The weakest correlation is found for the field strength of sunspots which is only influenced by strong fields.

2.3 Fabry–Pérot Versus Slit Spectropolarimetry of Pores and Active Network: Analysis of Interferometric BIdimensional Spectrometer (IBIS) and *Hinode* Data

As noted in Section 2.1, deriving chromospheric magnetic structure presents several difficulties but using the new tool of imaging spectropolarimetry has considerable potential. The goal is to constrain the magnetic free energy in the solar atmosphere, which is the cause of many of the Sun's most interesting observable phenomena (flares, CMEs), yet measurements of this free energy are notoriously difficult to obtain.

Line-of-sight (LOS) components of photospheric magnetic fields have been measured using circularly polarized light routinely for over 50 years. However such measurements set no constraints on the free magnetic energy. It was not until credible measurements of the full polarization vector became available that the free component of the magnetic energy became something amenable to observation. But several difficulties arise. The magnetic virial theorem relates the total magnetic free energy in a volume overlying a surface to the vector field measured at that surface, provided the surface is in a force-free state. Most vector field measurements are made in photospheric lines where, outside of sunspot umbrae, the fields are far from force-free. Thus, one must either extrapolate the field into the overlying atmosphere, or make measurements higher in the atmosphere where the field is close to force-free (the ratio of gas-to-magnetic pressure, plasma $\beta \ll 1$). The first option has been pursued by many researchers with mixed success in essence because the problem is non-linear and is usually cast into force-free form incompatible with photospheric conditions, and is also ill-posed because of sensitivity to boundary conditions.

The second option, using slit spectrographs has shown some improvements. However, the current work by Philip Judge (HAO/NCAR), Alexandra Tritschler, Han Uitenbroek, Kevin Reardon (INAF-Arcetri), Gianna Cauzzi (INAF-Arcetri), and Alfred de Wijn (HAO/NCAR) shows that using an imaging spectropolarimeter to observe chromospheric lines is especially suited for studying the chromosphere magnetic field because it has the spatial coverage and high temporal cadence needed to follow dynamic fibril motions which mostly dominate the upper chromosphere. Such work is difficult with conventional slit spectrographs. By using measurements of the chromospheric vector field, a) the magnetic free energy in the overlying corona follows directly from the virial theorem; b) extrapolations into the overlying atmosphere can be made using a boundary condition which is itself force-free, unlike the photospheric case; and c) the change in regime from a forced (photospheric) to forcefree state (upper chromosphere and corona) can be probed.

Figure 2.3-1 presents a comparison between IBIS and *Hinode* data, showing clearly that the imaging spectropolarimeter can provide the needed accuracy after calibration and removal of seeing and instrumental induced crosstalk while having the advantage of simultaneously covering the entire region of interest. They have demonstrated the fidelity of a two-dimensional filtergraph instrument, IBIS, for accurate Stokes V measurements at high angular resolution, by verification through almost simultaneous measurements from the Spectro-Polarimeter on board the *Hinode* satellite. They have demonstrated that high cadence, high angular resolution monochromatic images of fibrils in Ca II and Hα, seen clearly in IBIS observations, can be used to improve the magnetic field constraints, under conditions of high electrical conductivity. Such work is possible only with time series data sets from two-dimensional spectroscopic instruments such as IBIS, under conditions of good seeing.

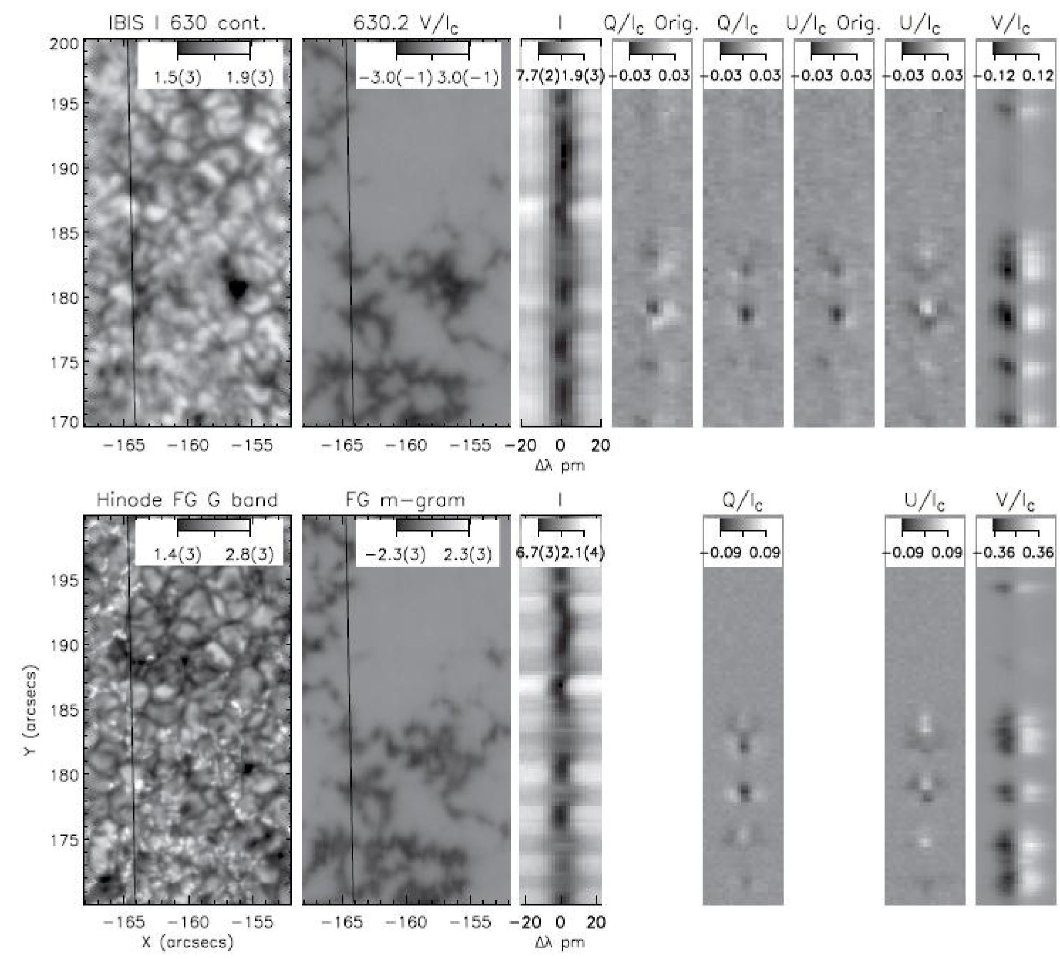


Figure 2.3-1. *Typical IBIS and Hinode SP polarimetric measurements of the 630.2 nm line. The upper panels show IBIS data, the lower show Hinode data. The leftmost column shows intensity images, the next column magnetograms, from IBIS (($V\lambda 0$+6pm −$V\lambda 0$−6pm)/IC, $\lambda 0$ = rest wavelength) and the FG instrument on Hinode (in Mx cm^{-2}). The near-vertical line shows the position of the Hinode slit at 14:36:52 UT, from which the six rightmost images of Stokes profiles as a function of wavelength and position along the SP slit are taken. QU data marked "Orig." are before subtraction of crosstalk and a final rotation in the polarization plane, the unflagged QU data include these corrections. IBIS profiles are extracted from the data closest in time and space to the SP measurements. Color scales are shown at the top of each image, where $x \cdot y(z) \equiv x \cdot y \times 10z$.*

2.4 Digitizing the NSO/SP Flare Patrol

In collaboration with the New Jersey Institute of Technology (NJIT), we have started digitizing NSO's historic Hα flare patrol data, which are on 35 mm film. These data will become part of the NSO Digital Library. The flare patrol operated for three solar cycles and is an important historical data set for understanding the long-term behavior of solar activity. The flare patrol consisted of on and off band Hα images taken at a one-minute cadence on a daily basis. The Improved Solar Observing Optical Network (ISOON) and the SOLIS Full-Disk Patrol have replaced the older flare patrol, which is now closed. NJIT obtained funding to digitize their archives from NSF and have been working on our archive as resources permit. It is not clear that NJIT will have sufficient funding to digitize all of the Sac Peak data. We have also digitized the Ca II K-line spectroheliograms from 1965-2002 and will add that data to the Digital Library.

2.5 Meridional Circulation during the Extended Solar Minimum: Another Component of the Torsional Oscillation?

Meridional circulation has become an important player in the flux-transport solar-dynamo models. Until the development of local helioseismology methods, the observation of meridional circulation was limited to the surface layers by tracing magnetic elements. Although the full picture of the meridional circulation throughout the convection zone remains elusive, and recent studies suggest that very long series of data are required to infer the flows deep down, local helioseismology has been able to give detailed information on these flows in the subsurface layers.

Irene González Hernández, Rachel Howe, Rudi Komm, and Frank Hill have shown that a component of the meridional circulation develops at medium–high latitudes (40°–50°) before the new solar cycle starts. Like the torsional oscillation of the zonal flows, this extra circulation seems to precede the onset of magnetic activity at the solar surface and moves slowly toward lower latitudes. The behavior of this component, however, differs from that of the torsional oscillation regarding location and convergence toward the equator at the end of the cycle. The observation of this component before the magnetic regions appear at the solar surface has only been possible due to the prolonged solar minimum. The results could settle the discussion as

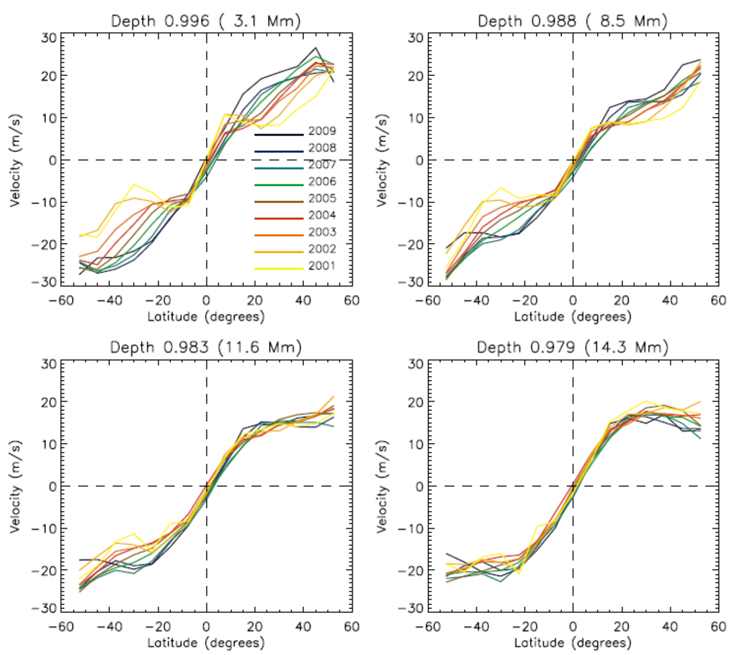


Figure 2.5-1. *Yearly averages of the meridional flow obtained by ring-diagram analysis of continuous GONG data at four different depths are shown. The variation with the solar cycle clearly observed at the superficial layers is less pronounced at deeper layers. The extra circulation (bumps) is also clearly visible in the shallow layers.*

to whether the extra component of the meridional circulation around the activity belts, which has been known for some time, is or is not an effect of material motions around the active regions.

González Hernández and colleagues have found, for the first time, a conclusive proof that the extra circulation, or bumps, of the meridional circulation under the solar surface is independent of the presence of surface magnetic activity. Spruit (2003, *Solar Physics*, 213, 1) presented a model that explains the torsional oscillation as a geostrophic flow due to the lower subsurface temperature in active regions. The model predicts the appearance of flows from the edges toward the center of the main latitude of magnetic activity, a meridional version of the torsional oscillation with a maximum amplitude of ~6 ms^{-} at the surface. The model also predicts a rapid decline of these oscillations with depth, which would disappear below 30 Mm. These results are consistent in amplitude with this model. However, their observations show a more rapid attenuation of the inflows with depth, which disappear around 10–14 Mm and they observe these flows at medium–high latitudes in the absence of surface activity.

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 until 2009, the NSO did not implement multiple-task time carding for its scientific staff, but this was done in FY 2010. This is critical because of the need to clearly separate any effort expended on ATST construction, since under MREFC rules we cannot use base-funded activities to support construction efforts. On the other hand, we will use base supported activities to prepare NSO for operations in the ATST era. These efforts will include developing multi-instrument support techniques and data handling, establishing an ATST data center, development of 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 how the NSO scientific staff divided their time in FY 2010 for research, administration and/or management, instrument development, EPO activities, etc. Individual research and service plans for NSO scientific staff are contained in Appendix H.

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 – Optical Design; ATST Instrument Engineer.

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

Craig Gullixson – DST Technical and Project Manager.

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

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; Associate Director for ATST work packages at Sac Peak.

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

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

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

3.1.2 Air Force Research Laboratory Staff at Sunspot

Richard C. Altrock – Coronal structure and dynamics.

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

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.

***Nina V. Karachik** – Solar helicity and activity.

3.1.4 Thesis Students

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

Sarah Jaeggli (University of Hawai'i) – Facility Infrared Spectrometer and solar polarimetry.

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.

3.2 Tucson-Based Scientific and Key Management Staff

*(*Grant-supported staff)*

3.2.1 NSO Staff

Luca Bertello –Solar vector magnetic fields; helioseismology; SOLIS Data Scientist.

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; GONG Program Scientist.

Frank Hill – Solar oscillations; data management; 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.

Anna Pietarila – Chromospheric dynamics and magnetism; spectropolarimetry.

Priscilla Piano – Administrative Manager: Director's office and Tucson site support; NSO grants and NSO/Tucson site budget management.

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.__ – Solar physics; waves; supergranulation.

*__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

*__Olga Burtseva__ – Time-distance analysis; global helioseismology; leakage matrix.

*__Michael Dulick__ – Molecular spectroscopy; high-resolution Fourier transform spectrometry.

*__Kiran Jain__ – Helioseismology; solar cycle variations; ring-diagram analysis; sub-surface flows.

*__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 Scientific Staff Estimated Percent FTE by Activity (FY 2010)

Name	Adm/Mgt[1]	Research[2]	EPO[3]	Project Support	User Support	Internal Comm.	External Comm.	TOTAL
Allen, W.F.		100						100.0
Bertello, L.		40		30	30			100.0
Burtseva, O.		52.2		23.5	24.3		0.0	100.0
Dulick, M.					100.0			100.0
Elmore, D.F.		11.0	1.0	72.0	8.0	2.0	6.0	100.0
Giampapa, M.S.	70.0	10.0	4.8	3.0		2.9	9.3	100.0
González Hernández , I.	2.0	59.0	6.0	15.0	15.0	1.0	2.0	100.0
Harker-Lundberg, B.J.		95.7	4.3					100.0
Harvey, J.W.	6.8	19.5	0.0	30.2	36.5	4.3	2.7	100.0
Hill, F.	75.8	13.1	4.4	4.1		1.0	1.6	100.0
Howe, R.		69.7	7.3	11.0	12.0			100.0
Jain, K. (50%FTE)		48.0	1.0				1.0	50.0
Karachik, N.V.		100.0						100.0
Keil, S.L.	35.0	5.0	5.0	45.0		5.0	5.0	100.0
Kholikov, S.S.		62.3		23.4	14.3			100.0
Komm, R.W.		90.0		5.0	5.0			100.0
Leibacher, J.W.	24.7	37.7	3.6	16.0		5.7	12.3	100.0
Penn, M.J.	0.0	67.4	12.3	4.8	10.5	5.0	0.0	100.0
Petrie, G.J.D.		50.0	15.0	30.0			5.0	100.0
Pevtsov, A.A.	2.0	29.7	2.8	20.9	40.8	1.2	2.6	100.0
*Pietarila, Anna (N/A)								
Rimmele, T.R.	53.9	5.0	3.9	20.4	8.8	4.0	4.0	100.0
Sherry, W.H.		94.0	3.0			3.0		100.0
Toussaint, R.M.		1.0	1.0	48.0	50.0			100.0
Tripathy, S.C.		96.0	1.0				3.0	100.0
Tritschler, A.		18.4	5.4	35.5	38.0	2.7	0.0	100.0
Uitenbroek, H.		29.8	7.6	19.4	28.3	6.8	8.1	100.0
Upton, R.S.				100.0				100.0
Woeger, F.		35.0	10.0	25.0	20.0	10.0		100.0

*New staff; statistics unavailable

[1]Administrative and/or Management Tasks

[2]Research, including participation in scientific conferences

[3]Educational 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.

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 2011 start for ATST site construction, we expect to achieve full scientific operations in 2017/2018. Until the ATST is online, the solar community relies on the DST for high-resolution imaging and spectropolarimetry in the visible and near IR 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 4.1.1). 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, including its advanced AO system.

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 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 jointly between NJIT and NSO. 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, contingent on available manpower.

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 diffraction-limited achromatic reflecting Littrow spectrograph allows for diverse wavelength coverage. A unique feature of FIRS is the multiple-slit design, which allows high-cadence, large FOV scans (four times faster than SPINOR and DLSP), a vital feature for studying dynamic solar phenomena such as flares. The high-order Echelle grating allows for simultaneous multi-wavelength observations and thus 3-D vector polarimetry. The detector is a 1K × 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 was becoming out-dated and difficult to maintain. SPINOR extends the wavelength of the ASP from 450 nm to 1650 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 and FIRS, are the primary instruments for joint observations with *Hinode* as they will also be for the recently launched Solar Dynamics Observatory. SPINOR, IBIS and FIRS augment capabilities for research spectropolarimetry at the DST and extend the productive lifetime of 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 (25-45 mA, depending on wavelength), 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. Both the narrow band and whitelight cameras have recently been upgraded to achieve a higher cadence of up to 15 fps. The instrument data pipeline is now integrated with the DST SAN. 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 Rapid Oscillations of the Solar Atmosphere (ROSA)

ROSA is a high cadence imaging system especially designed to observe at blue wavelengths. It comprises six high-speed cameras, and supporting computer and large local storage hardware. It achieves up to 30 fps and is designed and built by Queens University in Belfast, Northern Ireland, U.K. ROSA is normally operated at wavelengths between 350 nm and 656 nm. Currently data are stored on local disks attached to the camera computers. The instrument can be operated by the observers at the DST, but Queens university provides observing support for Pis from the U.K. A seventh, more blue sensitive camera is being purchased by Queens university to increase throughput at the shortest wavelengths.

4.1.7 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 and 1980s ICC, 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, 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, supplemented by several media stations, computers that are at the disposal of observing scientists to copy their data to portable media of their preference.

4.1.8 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 one of 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 H_2O.

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 this large-format IR camera, the 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 some 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. Northridge) 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 was 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, low-noise 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. We now know that the temporal variations in the torsional oscillation presage some aspects of the behavior of the subsequent solar cycle, providing a forecast tool. 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.

GONG is close to completing the deployment of a new capability in the form of an H-alpha observing system. This system, funded by the U.S. Air Force Weather Agency (AFWA), provides a large-format 1-arcsec per pixel solar image in the H-alpha spectral line every 20 seconds. The images are processed and sent to AFWA within one minute of acquisition for flare detection and solar activity forecasting. The system has been installed at five of the six GONG sites at the time this document was prepared. AFWA has committed to supply GONG with a substantial amount of operational support to ensure that this observing capability is available while the ISOON network is developed, and to back up ISOON during times of maintenance.

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, and the U.S. Air Force is providing support as discussed above. There is no guarantee, however, 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 the outside funding be deemed insufficient. 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 upcoming Solar and Space Physics 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 2011.

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 were recently improved, and data 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 (photospheric and chromospheric) and full disk (photospheric) 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.

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 appearing (nearly) daily on the NSO Website. 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.

Detailed comparison between selected MDI and SOLIS (longitudinal) and SOLIS *Hinode* (vector) magnetograms has been conducted and reported at an October 2009 meeting of the Vector Magnetogram Comparison Group (VMCG). SOLIS/VSM and MDI longitudinal magnetograms correlated reasonably well; correlation between data from these two instruments is much stronger for stronger fields. Comparison with *Hinode* data has also indicated reasonably good correlation, although several areas of disagreement have been noted. Some differences could be due to difference in inversion techniques employed by two instruments. These issues were addressed at the VMCG meeting in October 2010 at Stanford University with results pending.

Data reduction for VSM He 10830 Å data has been improved. Initial pixel-by-pixel comparison indicates a close agreement between VSM and ISOON He 10830 Å images. Based on this comparison, "preliminary" status of VSM He 10830 data has been removed.

Comparative study of SOLIS and GONG synoptic maps suggests the need for a unified approach in constructing synoptic maps. A new set of synoptic data products from both SOLIS and GONG is now under development. Community input for NSO synoptic products has been sought via a splinter meeting on Synoptic Maps: Present and Future organized by NSO scientists during the 2010 SHINE meeting in Santa Fe, New Mexico. There are plans to continue working with the community on further improvements of NSO synoptic data products.

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 2-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. There are VME boards within the VSM and FDP, however, 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 required 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.

4.4.2 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 has been completed on a new data acquisition system (DAS) that is compatible with the high-speed Sarnoff cameras.

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. We are investigating a replacement for the current photospheric modulator package with a new modulator design by Meadowlark. A modulator package on loan underwent extensive testing in July 2010 with mixed results. Meadowlark agreed to supply another unit for evaluation in the August/September time frame.

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.

4.4.3 SOLIS Chromospheric Vector Magnetogram Capability

Successful launch of the Solar Dynamics Observatory is creating a unique stream of photospheric vector magnetograms, enabling "around-the-clock" studies of magnetic evolution in flaring and CME-producing active regions. On the other hand, photospheric magnetograms have limitations in studies requiring extrapolation of fields into the corona and, perhaps, interplanetary space. Chromospheric vector magnetograms are widely considered to be a much better option for such studies. Also, it is often difficult to infer true topology of horizontal magnetic fields in the chromosphere and above because photospheric magnetic fields (especially on small spatial scales) may close locally and not extend to the upper hemisphere. In that respect, chromospheric vector magnetograms may provide additional critical information not easily obtainable from photospheric observations. The capability of producing chromospheric vector magnetograms is a future upgrade of the SOLIS modulator; this will significantly enhance the understanding of topological properties of solar magnetic fields in the solar upper atmosphere, and potentially, improve the utility of SOLIS data in space weather forecasting.

4.5 Synoptic Program (GONG and SOLIS Merger)

The goal of merging the GONG and SOLIS programs is to create a national science program with a long-term perspective on solar/stellar variability and a space weather data resource. By merging the programs, we will achieve an economy of scale, while bolstering the support for processing and archiving SOLIS data.

Scientific goals of the merger include: understanding magnetic field generation and evolution; providing observations of the surface vector magnetic field that can be used to understand the build-up of magnetic energy in the solar atmosphere; understanding the solar cycle and long-term variation of solar activity; developing a long-term record of the variations of solar spectral irradiance which influence climate; providing constraints on solar and stellar dynamo models; and inferring the internal dynamics and structure of the Sun. A further goal is to use the expertise developed and apply it to asteroseismology. This will provide comparative dynamo models on other stars and help understand the range of stellar activity and thus possible variations in the solar output.

In addition to achieving economy of scale, there are several functional reasons for the merger. Having all synoptic telescope operations under a single NSO division will make it easier to move resources as needed. Having a single data processing and distribution center for synoptic solar data not only save resources but makes it simpler for the user to obtain data. The synoptic program will develop data products with user community input. In addition to providing scientific data, the synoptic program will support space weather programs, which in turn are providing operational funds.

We have already begun the integration of SOLIS and GONG data processing systems. AFWA operational support for GONG will begin in the fall of 2010. We also plan to complete the routine SOLIS VSM vector data processing by the end of 2010. The installation of the AFWA H-alpha instrument into the GONG systems is in its final stages. The final SOLIS instrument is scheduled for installation on the mountain by the end of the year and we will then integrate FDP data into the data center. Following the completion of the GONG H-alpha and SOLIS FDP, we will start the integration of the SOLIS and GONG instrument team. In 2011, we plan to install new SOLIS modulators that will allow SOLIS to make chromospheric vector field measurements. When ATST comes on line, we would incorporate the synoptic data processing into an NSO Data Center that includes all NSO data products.

As the synoptic program develops, we need to continue our development of a broad agency user base willing to contribute resources. We plan to actively participate in the Solar and Space Physics Decadal Survey by providing advocacy for long-term solar observations. The NSO Synoptic Program should become a national resource for space weather data, and this will be coupled with a vigorous science program with a long-term perspective.

4.6 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.

4.7 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, 2010, more than 22.9 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 has been installed. This system, named */newsolarch/* (for SOLIS, or solar archive), also holds the Digital Library contents. The */newsolarch/* system has 80 TB of on-line RAID5 storage. The Digital Library is fully supported by non-NSO funds, and is an important component of the Virtual Solar Observatory. We will soon be adding ISOON data and historical Sacramento Peak spectroheliograms scanned from film images.

Table 4. Telescope and Instrument Combinations FY2010/FY2011

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

Instrument	*Telescope*	*Comments/Description*
NSO/Sacramento Peak – OPTICAL IMAGING & SPECTROSCOPY		
High-Order Adaptive Optics	DST	60 - 70-mode correction
Interferometric Bidimensional Spectrometer (IBIS)	DST	Spectro-Polarimetry, 25-45 mA resolution, 543 nm – 854 nm
Facility InfraRed Spectro-Polarimeter (FIRS)	DST	R $\leq$ 200,000, 630 nm – 1650 nm
Spectro-Polarimeter for Infrared & Optical Regions	DST	R $\leq$ 200,000, 450 nm - 1650 nm
Rapid Oscillations of the Solar Atmosphere (ROSA)	DST	30 fps, 350 nm - 656 nm
Diffraction-Limited Spectro-Polarimeter	DST	6302 Å polarimetry, 0.1 arcsec and 0.25 arcsec/pixel
Universal Birefringent Filter (UBF)	DST	Tunable narrow-band filter, R $\leq$ 40,000, 4200 - 7000 Å
Horizontal Spectrograph	DST	R $\leq$ 500,000, 300 nm - 2.5 μm
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies
Littrow Spectrograph	ESF	R $\leq$ 1,000,000, 300 nm - 2.5 μm
Various CCD Cameras	DST	380 - 1600 nm; Formats: 256 × 256 to 2K × 2K
Correlation Tracker	DST	Tip/tilt correction
40-cm Coronagraph	ESF	300 nm – 2.5 μm
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å
NSO/Sacramento Peak – IR IMAGING & SPECTROSCOPY		
Horizontal Spectrograph	DST	High-resolution 1- 2.5 μm spectroscopy/polarimetry, R $\leq$ 300,000
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 μm spectroscopy/polarimetry
NSO/Kitt Peak – IR IMAGING & SPECTROSCOPY		
SOLIS Vector Spectromagnetograph (VSM)	KPST	1083 nm: Stokes I, 2000 × 1.1 arcsec, 0.35-sec cadence 630.2 nm: I, Q, U, V, 2000 × 1.1 arcsec, 0.7-sec cadence 630.2 nm: I & V, 2000 × 1.1 arcsec, 0.35-sec cadence 854.2 nm: I & V, 2000 × 1.1 arcsec, 1.2-sec cadence
SOLIS Integrated Sunlight Spectrometer (ISS)	KPST	380 – 1083 nm, R= 30,000 or 300,000
Vertical Spectrograph	McMP	0.32 - 12 μm, R $\leq 10^6$
1-m Fourier Transform Spectrometer (FTS) (FTS	McMP	2200 Å to 18 μm, R $\leq$ 600,000
NSO Array Camera (NAC)	McMP	1 - 5 μm, 1024 × 1024, direct imaging, and full Stokes polarimetry from 1- 2.2 μm
CCD Cameras	McMP	380 - 1083 nm, up to 1024 × 1024 pixels
IR Adaptive Optics	McMP	2 – 12 μm
Planetary Adaptive Optics	McMP	0.4 - 0.7 μm, planetary or stellar sources down to ~3rd magnitude at the stellar spectrograph
Stellar Spectrograph	McMP	380 – 1083 nm, R $\leq 10^5$
Image Stabilizer	McMP	Solar, planetary or stellar use to 7th magnitude for use with the vertical or stellar spectrograph
Integral Field Unit	McMP	6.25" × 8" field, 0.25" per slice, producing a 200" long-slit. Optimized for 0.9 - 5.0 μm on the vertical spectrograph
Wide-Field Imager	McME	Astrometry/Photometry, 6 arcmin field
NSO/GONG – GLOBAL, SIX-SITE, HELIOSEISMOLOGY NETWORK		
Helioseismometer & Magnetograph	California, Hawaiʽi, Australia, India, Spain, Chile	2.8-cm aperture; imaging Fourier tachometer of 676.8 nm Ni I line; 2.5 arcsec pixels; 1-min. cadence.

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 2009 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 (≤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)

A Science Working Group met November 2-4, 2010 at Stanford University. The SWG focused on instrumentation development updates, requirements verification and clarification of a few instrument requirements that are still under discussion. During its 2009 meeting, 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 heard a report from ATST project management on the status of the instrumentation project funding within the overall project funding. An update was presented on potential development of detectors that meet the polarimetry requirements.

The ATST science team has made a significant effort to develop and refine the Operations Concept Definition document (OCD) using science use cases for first-light instrumentation developed by the SWG. The OCD is a living document that is guided by the ATST Operations Plan and the high level policies and operational concepts detailed in the NSO Operations Plan

(OP), which is under development. During the 2010 SWG meeting, the SWG members were updated and asked to comment on the current status of the OP and the OCD.

The main focus of the 2010 SWG meeting was the drafting of individual science verification plans for first-light instruments as well as a science verification plan for the multi-instrument system. Science verification observations to be conducted at the very end of the construction phase and before formal handover to operations will be defined by the SWG. These observations will be limited in scope with the specific goal of assessing whether instruments operate properly and efficiently with all other subsystems of the facility.

Involvement of the SWG in organizing the 2nd ATST/EAST (European Association of Solar Telescopes) workshop in the U.S. in 2011 was also discussed and an organizing committee was formed.

5.1.2 ATST Project Organization

NSO Director Steve Keil is the ATST Project Director. The science team as well as the engineering team associated with the project work packages at Sunspot, New Mexico , report 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 Proposed Site and Permitting

5.1.3.1 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, $C_n^2(h)$ 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/finalreport*. The overall ATST design approach and impact of the selection of Haleakalā on the overall design has been reported previously.

5.1.3.2 Site Permitting

Environmental permitting for ATST at the selected Haleakalā site required the preparation of an Environmental Impact Statement (EIS) as defined by Federal and State of Hawaiʻi statutes. In 2005, the Maui-based firm of KC Environmental (KCE) was contracted to lead that effort. Following the published Notice of Intent (NOI) 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 included: the impacts on Haleakalā as a cultural site to Native Hawaiians, impacts to the viewshed and viewplane, due to the telescope's required height and white color; the potential impact of ATST on biological resources, particularly the endangered Hawaiian petrel; and increased traffic on the Haleakalā National Park road during construction and operation. Comments from the public and concerned agencies were taken into account in the preparation of the Draft EIS (DEIS).

Following release of the 2006 DEIS, the public was given the required 45-day public comment period in which to submit written comments on the DEIS. Three public meetings were held on Maui during that period to allow the community to comment on the document, either verbally or by submitting written comments. The input received largely reinforced the concerns that had previously been identified. The adjacent Haleakalā National Park, in particular, raised concerns about the construction-related use of the 11-mile section of highway that runs through and is maintained by the Park. (Access to the Haleakalā High Altitude Observatory Site (HO) is through the National Park.) The Park 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 comments pointed out the historic nature of the Haleakalā highway itself and the potential for damage caused by construction traffic. The Federal Aviation Administration (FAA), which operates a repeater station on Haleakalā for air-to-ground communication, 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 (USFWS) 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 USFWS 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.

The Supplemental Draft Environmental Impact Statement (SDEIS) was published on May 8, 2009 and was prepared in response to public and agency comments of the DEIS published in September 2006. In a number of respects, the SDEIS was considerably revised from the DEIS; comments received warranted additional surveys and studies, which were completed after the DEIS was published. The SDEIS was substantially changed from the DEIS of September 2006. The public was again given a 45-day comment period with three public meetings held to allow further public comment.

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. A Programmatic Agreement with members of the community and various agencies was fully executed in September 2009. As the Lead Agency for the Proposed Action, the National Science Foundation is implementing the Programmatic Agreement, and significant progress has been made, especially with the formation of the Native Hawaiian Working Group.

The Final EIS was completed in July 2009, and a Record of Decision was signed by the Director of the NSF on December 3, 2009. With the release of the FEIS and the Record of Decision, the project is proceeding with the Conservation District Use Permit (CDUP), as required by Hawaiian statute.

5.1.4 Project Progress

Design activities during the past year were focused on completing follow-up activities based on committee recommendations from the Final Design Review (FDR) held in May 2009. Work also focused on completing bid packages in preparation for the 2010 construction start.

The ATST project accomplished several major milestones during FY 2009 and FY 2010, including the NSF conducted Final Design Review, completion of a supplemental EIS on the road through Haleakalā National Park, as well as the Final EIS. Appendix E1 provides additional information on project milestone accomplishments during FY 2010. The ATST project team continues to draw from a broad range of resources, which include members of the NSO staff, individuals from other organizations, and Co-PI teams that review instrumentation, operations, and design issues. As construction begins, several new hires have been added to the project team (e.g., a contracts officer was hired as recommended by the NSF FDR committee).

5.1.4.1 Support Facilities

A Professional Services Sub-award Contract was awarded to M3 Engineering and Technology Corporation on October 15, 2009 to perform Architectural and Engineering Services for the design development of the ATST Support Facilities.

A design and development review was held September 29 – 30, 2010 and represented approximately a 50% completion level for the overall design. Construction drawings and specifications were produced for site civil work and infrastructure, and architectural, structural, mechanical, electrical, plumbing, and life safety for the Support Facilities, which include the support and operations buildings, the pier, lower enclosure, and utility building. Changes and refinements will be incorporated into the design development documents as recommended by reviewers and approved by the ATST engineering team prior to advancement to the construction documents phase.

A separate set of construction documents will be produced to support the commencement of site preparation required for geotechnical testing, site clearing and leveling, major earthwork activities, utilities, and construction infrastructure. Following the completion of this package, construction documents for the full defined scope of the Support Facilities will be prepared. The documents will be developed in incremental steps at approximately 70% and 95% levels of completion and presented in review meetings. At completion of the construction documents phase, drawings and specifications will be incorporated into bid packages for construction contracts to be administered by ATST.

5.1.4.2 Optical Design

The ATST is an off-axis all-reflecting Gregorian telescope. The off-axis design provides the optimal stray-light performance, which is critical for coronal observations. The all-reflecting characteristic is the only option that allows observations at wavelengths from 300 nm to 12 mm 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. Calibration and polarization optics used during normal operations are located at the Gregorian focus. The beam is then nearly collimated and relayed to the coudé observing station.

During 2010, the project made no changes to the optical design outside of the coudé lab but has continued to improve the design within the coudé lab. These changes support evolving requirements of both the adaptive optics system and instrumentation that will be operated simultaneously.

5.1.4.3 Telescope Mount Assembly (TMA)

The main focus on the Telescope Mount Assembly this past year has been the final preparation for tender, processing and review of the TMA contract proposals. There was a significant amount of final internal reviewing of both the technical specification, statement of work, contract and interface control documents in preparation for tender release. The Request for Proposal (RFP) process was started with a formal request for notes of interest and prequalification information from potential vendors in mid January 2010. The RFP package was then released on the March 1, 2010 to the pre-qualified vendors.

As part of the tender preparation process, all vendors were required to attend a vendor conference and site visit on Maui. This consisted of presentations by the ATST project team on the TMA performance requirements, the scope of work and site requirements.

Proposals for the TMA contract were received on May 28, 2010. The review of these proposals was undertaken by a Source Selection Board (SSB) consisting of ATST project personnel and an independent reviewer. As part of the review process, select members of the SSB visited some of the vendors for clarification of information provided in their proposals. The TMA Source Selection Board recommendation to the ATST Project Manager was submitted in August 2010.

5.1.4.4 Enclosure

The main focus this past year has been on contracting the major work package for the Enclosure. This has included writing the Request for Proposal documents, then competitively bidding the package. The RFP was sent to a relatively large number of potential bidders. The bidders were asked to attend a vendor conference and summit visit on Maui. Five quality proposals were received in March 2010 and reviewed by the Enclosure Source Selection Board. Site visits for purposes of clarification of proposal information were made by a subset of the SSB to the highest ranked vendors. An SSB recommendation was then presented to the ATST Project Manager. Contract negotiations were undertaken with the selected vendor, AEC Idom. In June 2010, a kick-off meeting was held in Minneapolis, Minnesota with AEC Idom to begin the initial work. Since that time, AEC Idom has made good progress on the basic layout, and structural/mechanical designs of the Enclosure. In addition, the Enclosure Control System (ECS) was added to AEC Idom's scope of work in September 2010.

5.1.4.5 Wavefront Correction (WFC)

The ATST wavefront correction system uses deformable and tip-tilt mirrors to improve the delivered image quality by compensating for image distortions introduced by the atmosphere and telescope optics. The system is tasked with producing the finest resolution images that a 4-meter mirror can deliver, which is ultimately limited by the diffraction limit of the 4-meter aperture. The ATST WFC must achieve high Strehl (or high percentage of light within the diffraction limited image) requirements at visible and infrared wavelengths called for in the Science Requirements Document. To do this, 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:

1. *A high-order adaptive optics system (HOAO)*. This sub-system detects atmospheric seeing distortions at >2 kHz rates to make corrections with a deformable mirror that nulls out the distortions. 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 adaptive optic (AO) systems deployed at the Dunn Solar Telescope located at NSO/Sacramento Peak.

2. *Active optics system (aO)*. The active optics 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.

3. *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 and will keep the light going down the correct axis for proper illumination of the various instruments.

4. *Blending*. Information from different wavefront sensors (e.g., HOAO 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., when sending 2kHz signals to the DM), or indirectly through the WCCS when the rates for data are much lower (<1 Hz). The WCCS is a system with a 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 and passes them on to the appropriate system. The main task of the WCCS is to blend information from the operating wavefront correction systems to determine corrections 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.

The development effort, now fully funded, is focusing on final specification of the system, resolving some final decisions, and exploring procurement and fabrication options. One area of exploration this year is focused on determining if graphical processing units (GPUs) can be used as the "brains" of the HOAO system. GPUs form the heart of gaming systems such as Xbox, can have faster computation times for certain types of computations than normal CPUs, and can be considerably less expensive to implement than the current technology defined in the baseline design which use Digital Signal Processors (DSPs) to perform the fast calculations. It is not yet clear if the GPU technology can meet the demands of processing 50 image correlations in less than 0.0005 seconds of time, but they appear to be tentatively close. It has already been shown that the DSPs can perform such fast computations, but at a much higher cost for implementation. The GPU option will also open the door to affordable multi-conjugate AO (MCAO) systems in the near future and seen as a second generation upgrade for the ATST WFC system.

Other areas of work have been in the refinement of the system design, the receipt of studies from potential DM and Tip-Tilt vendors, and the fine tuning of the optical design for the WFC sensor channels. Both the Tip Tilt and DM mirrors should be ready for procurement early in the new calendar year.

The WFC team has expanded at the end of this year to bring on board a full-time project manager, a GPU software expert, and a postdoc position to assist with WFC project and systems engineering.

5.1.4.6 Software

The software team expanded to six people at the start of construction phase funding, with additional team members focused on the Instrument Control System (ICS), the Data Handling System (DHS), and the Virtual Camera Controller (VCC). The DHS, ICS, and Observatory Control System (OCS) are under construction and beginning to meet the major requirements of their respective first releases, all due near the end of 2011 or beginning of 2012. The VCC has begun its design work in conjunction with the work on the camera requirements, hardware, and data handling.

The Telescope Control System is now under contract, along with the software development of the enclosure control system. This contract has a preliminary design review in October 2010. Contracts for the software control of the telescope mount assembly, M1 assembly, and Top End Optical Assembly are to be issued later in 2010.

The Common Services Framework has released its first construction-ready version. Team members are now supporting contractors and developers in its use through technical forums and on-site classes. Additional features are planned for the next formal release in June 2011.

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

5.1.5 Construction Phase Planning

In January 2010 the ATST project transitioned from design to the construction phase. Support of the Conservation District Use Application (CDUA) process in Hawai'i continues. Near-term efforts are concentrating on establishing contracts for the major sub-systems and long-lead items (e.g., M1 blank, enclosure, TMA, M1 Assembly), detailed optical feeds to instruments, 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 are being executed.

Construction phase management and systems engineering efforts are focused on requirements for the construction phase including the integration, testing, and commissioning phase. The project has considered a range of possible subcontracting options during the construction phase and developed these options with interface requirements and project organization in mind. As presented at the NSF conducted FDR, the interface control document (ICD) system and the work breakdown structure (WBS) have been refined to cover the entire period through the construction phase. As was done in the design phase, the WBS is consistent with the subsystems, and each work package has an accounting number system that corresponds to the WBS and ICD organization.

Funds have been budgeted to each of the major work package for the construction phase. Contingency, based upon risk analysis presented at the NSF conducted FDR, is held and managed centrally by project management.

5.1.5.1 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 and IT&C are essential for keeping the end-project goals in mind.

During the initial construction phase, the detailed plans for transitioning to operations that were developed in the D&D phase are being refined and used to continue life cycle planning and help prepare the National Solar Observatory for the operational phase of the ATST.

Current planning has calendar year 2018 targeted for obtaining the first scientific data with an ATST instrument. 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 will also be well underway.

5.1.6 Funding

Funding from the American Recovery and Reinvestment Act of 2009 (ARRA) was made available to the project at the level of $146M, and from normal appropriations an additional $7M in FY 2009 and $13M in FY 2010. Funding on the order of $20M per FY through the run out of the project is planned, with the total funding equal to $297.928M. Table 5.1-1 is shown in the NSF FY 2011 Budget Request to Congress.

Table 5.1-1. Appropriated and Requested MREFC Funds for the Advanced Technology Solar Telescope
(Dollars in Millions)

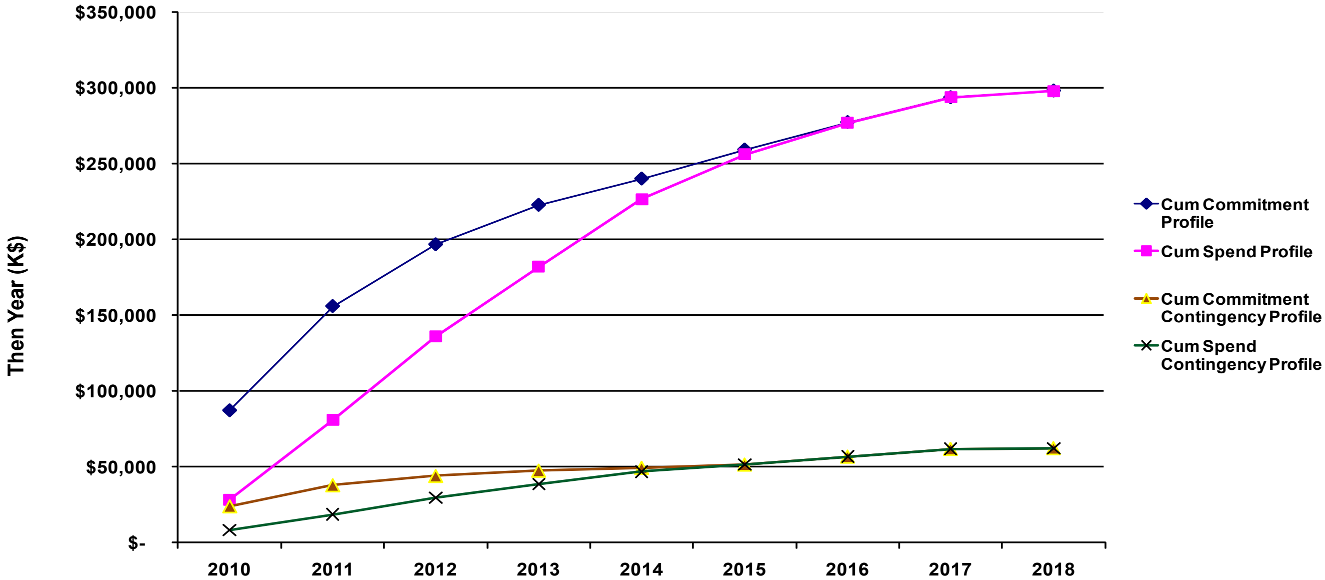
	FY 2009	FY 2010 Estimate	FY 2011 Request	FY 2012 Estimate	FY 2013 Estimate	FY 2014 Estimate	FY 2015 Estimate	FY 2016 Estimate	FY 2017 Estimate	Total
Regular Approps	$7.00	$13.00	$17.00	$20.00	$20.00	$20.00	$20.00	$20.00	$14.93	$151.93
ARRA	146.00	-	-	-	-	-	-	-	-	146.00
ATST TOTAL	**$153.00**	**$13.00**	**$17.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$20.00**	**$14.93**	**$297.93**

In January 2010, adequate construction funding was provided 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 transitioned at that time fully from D&D funding to construction funding. 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 FDR committee made recommendations regarding the potential impact of ARRA funds and the associated buy-American restrictions, as well as recommendations regarding schedule contingency and instrumentation management. The funding profiles proposed in the construction proposal, cost review, PDR and FDR were based on technically driven schedules.

5.1.6.1 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. The American Recovery and Reinvestment Act provided an additional $3.1M. The $3.1M was 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, and to support software efforts.



	2010	2011	2012	2013	2014	2015	2016	2017	2018
Cum Commitment Profile	$ 87,054	$ 155,811	$ 196,546	$ 222,577	$ 239,907	$ 259,034	$ 277,129	$ 293,516	$ 297,928
Cum Spend Profile	$ 28,408	$ 80,905	$ 135,843	$ 181,953	$ 226,549	$ 256,134	$ 276,884	$ 293,516	$ 297,928
Cum Commitment Contingency Profile	$ 23,880	$ 37,782	$ 43,947	$ 47,442	$ 49,340	$ 51,488	$ 56,748	$ 61,853	$ 62,339
Cum Spend Contingency Profile	$ 8,196	$ 18,613	$ 29,510	$ 38,486	$ 46,827	$ 51,414	$ 56,748	$ 61,853	$ 62,339

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

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 solar space missions, such as *Hinode* and SDO. 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 photospheric 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. Observing 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.

Although many of the above tasks may soon be addressed using SDO/HMI vector observations, SOLIS' future capability of producing chromospheric vector magnetograms will complement SDO photospheric data and has a potential of significantly improving the understanding of topology of magnetic fields throughout the solar atmosphere. As a spectrograph-based magnetograph, SOLIS will be indispensible in calibrating and removing variations across field-of-view possibly existing in filter-based SDO/HMI magnetograms. Such variations are well-known to exist in MDI magnetograms.

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 US, Europe/Africa (+8 hours) and western Australia/Asia (-8 hours). It should be noted, parenthetically, that the ATST site on Haleakalā 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 FY 2007 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, and together with these potential partners, a proposal was submitted to the NSF/ATM. The proposal received excellent reviews but was not funded.

NSO continued to seek funding for an additional SOLIS VSM through a special MRI-R^2 opportunity in September 2009. A joint proposal was submitted with the California State University, Northridge (CSUN) as the lead institution. The CSUN Vector Spectromagnetograph (CSUN-VSM) project aimed at building a state-of-the-art vector magnetograph based on the successful first version of the SOLIS NSO-VSM. The instrument was to significantly expand the observational capabilities of the solar physics group at CSUN and would have created a unique opportunity for the students and faculty of CSUN, as a designated Hispanic-serving institution, to participate in a modern instrument building activity for forefront space weather and solar research. The CSUN-VSM was to be located at the Big Bear Solar Observatory to exploit the superior synoptic solar observing conditions at that site. In addition, a redesign of the modulator was to allow the measurement of the magnetic field vectors at two solar heights in order to understand the three-dimensional magnetic field structure of solar active regions – a major goal of the CSUN group.

The CSUN-VSM, together with the NSO-VSM (after its relocation to a suitable site), would have established the foundation for a global VSM network to provide the world scientific community with uninterrupted full-disk observations of solar vector magnetic fields in both the photosphere and chromosphere which is essential for space weather prediction. Unfortunately, in January 2010, the proposal failed to make it to the next level of review. NSO will continue to actively pursue future 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. 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 3,800,000 files totaling 25 TB distributed during the period July 1, 2010, through November 30, 2010. The VSO has developed a mirrored DRMS (Data Record Management System) for NASA's SDO mission, provided a command-line interface for use in the popular IDL programming environment, and is linked to community-prvided services such as Helioviewer. 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 *http://vso.nso.edu/*.

In the time frame covered by this 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 instrument-driven 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 major step towards the establishment of the NSO Synoptic Program. This merging is in the areas of processing filtergrams, and producing synoptic maps of the magnetic field.

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 into 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/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 SDO and other space missions as well as explore commercial venues (e.g., Google) for data storage and retrieval.

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 is developing a proposal to broaden participation in its outreach and staffing, as well as in science in general. Part of our initial aims are 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.
  - Strengthen our Summer Research Assistantship for graduates program.
  - 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.
  - Strengthen our Research Experience for Teachers (RET) program.
  - Make RET lesson plans available on the WWW.
  - 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.
  - Increase the relevance and content of our WWW outreach.
  - Develop outreach materials for both classroom and public distribution.
  - 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.
    - Create ties with schools and universities serving underrepresented minority groups.

Current NSO EPO resources includes the ~1.0 FTE of scientific staff time (~$115K) shown in Table 3.1, $132K from NSF to support the REU/RET programs, one full-time EPO staffer (~$90K), support for a visitors center and tours of $50K, and part-time support from several members of the administrative and technical staff total approximately 0.5 FTEs ($55K). In addition, NSO transfers $112K to NOAO to participate in their EPO programs. The total resources going into EPO are thus 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 our science and support staff members. In addition, NSO provides funding to the NOAO Public Affairs and Educational Outreach (PAEO) group and participates in several of their programs. Thus 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 of Scientists

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 of scientists by conducting annual programs that offer undergraduate, graduate students, and middle- and high-school teachers opportunities to participate in astronomical research (see Table 6.1-1).

Opportunities are provided at our Sunspot, New Mexico and our Tucson, Arizona sites. As we build-up staff in for ATST operations these programs will be extended to Maui. 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 2010, participants in the NSO program included five females and two males.

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.

Table 6.1-1. Number of Participants in NSO Educational Outreach Programs (2003–2010)

Year	Graduate (SRA)	Undergrad (SRA)	Undergrad (REU)	Teachers (RET)	Postdoctoral Fellows
2010	6*		7		5
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 6.1-2, 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 2010 included (chronologically):

- Exhibit at New Mexico Science Teachers Association convention, Ruidoso, NM (Oct. 2009).
- Exhibit at the annual national 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).

- Sun Balloon exhibit for the 40th anniversary of the Apollo 12 landing, New Mexico Museum of Space History (Nov. 2009).
- Exhibit at the American Geophysical Union in San Francisco (Dec. 2009).
- Participation in the AURA Diversity Summit in Tucson (Feb. 2010).
- Prepared to exhibit at the Feb. 2010 National Society of Black Physicists/National Society of Hispanic Physicists convention in Washington (canceled by NSBP).
- Participation in a Wavelength and Photosynthesis activity in a grades 9-12 astronomy workshop sponsored by the University of Hawaiʻi in Kihei, Maui (Mar. 2010).
- Sun Balloon exhibit to six science classes (about 200 students) at Ruidoso High School, Ruidoso, NM (Apr. 2010).
- Participation in three events at the AAS/Solar Physics Division Meeting in Miami: Exhibited at the meeting proper, talked with students and teachers at the education receptions, and particiapted in the AstroZone Exploration Station at the Miami/Dade Public Library the day before the conference (May 2010).
- At the May 2010 AAS/SPD meeting, NSO agreed to take the lead on local preparations for the EPO committee when SPD meets in Las Cruces in 2011.
- Sun Balloon exhibit at a star party at Brantley Lake State Park near Carlsbad, NM (Jun. 2010).
- Sun Balloon exhibit and displays at the Univeristy of Arizona "Sun Day" in Tucson; public talks about the Sun were presented by two NSO scientists and an NSO grad student (Jun. 2010).
- Sun Balloon exhibit and short presentations to about 150 teachers about NSO educator resources during the Scientifically Connected Communities event (SC^2) held by New Mexico State University in Las Cruces (Jun. 2010).
- Sun Balloon exhibit at the Lunt Solar Observing Convention held in Tucson (Jun. 2010).
- NSO representation at two meetings of the Youth ACTION program being developed under the leadership of the U.S. Forest Service in Alamogordo. This represents an opportunity to attract a larger audience to Sunspot for a broader range of activities.
- Lecture presentations to approximately 400 K-8 students attending New Mexico Space Academy in Alamogordo and Las Cruces on six occassions (June-July 2010).
- Sun Balloon exhibit at "Sun Day" at the New Mexico Museum of Natural History in Albuquerque (Jul. 2010).
- Sun Balloon exhibit at the Cosmic Carnival, International Balloon Museum in Albuquerque (Aug. 2010).
- Lecture presentations on solar science and hosted public viewing on H-alpha and white-light telescopes just before a star party at Carlsbad Caverns National Park, NM (Aug. 2010).
- Exhibit and discussions on education materials at the annual Teacher Open House at the New Mexico Museum of Natural History, Albuquerque (Sept. 2010).
- Sun Balloon exhibit and discussions about solar science with about 200 K-6 students at La Promesa Charter School, Albuquerque (Sept. 2010).

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, Matthew Richardson, a graduate student in the Fisk-Vanderbilt Masters-to-PhD Bridge Program, started a summer research internship at NSO/Tucson with Frank Hill (NSO) and Keivan Stassun (Vanderbilt U.) as advisors. In August 2010, Matthew defended his thesis on "Solar Flares: A Possible Driving Mechanism of High-Frequency Global Oscillations" and received his Masters degree from Fisk University. He will be starting on his PhD at Vanderbilt University this academic year.

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 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 - 2010)

Year	2010	2009	2008	2007	2006	2005	% Participants
Male	2	3	4	2	1	5	43
Female	5	3	2	4	6	3	57
Minority*	0	2	0	1	0	0	7.5

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

6.1.3 Summer Schools

For four years beginning in 2006, 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 were 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 in partnership with the University of Hawaiʻi and the Center for Adaptive Optics. 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 through 2010 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 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 Hawaiʻi, 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 Hawaiʻi student is working on her thesis based on a University of Hawaiʻi 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-R^2 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 recent past, 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.

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 *http://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 2010, NSO procured most of the major elements of the Sunspot Solar System Model. The planet models and two large graphics were installed, and the remainder of the work is to be completed in October-November 2010. Installation of the highway signs was delayed by the need for state crew to repair damage from snow removal equipment after the winter's heavy snows. 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 are being translated into Spanish to help attract Hispanic audiences. NSO is developing 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.

During 2010 NSO worked with Interstellar Studios, producer of *400 Years of the Telescope*, on a proposal to produce an NSF-funded documentary on the Sun, incorporating ATST. If the proposal is funded, NSO would partner on production and distribution of education materials related to the project.

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.
- Extending our mentoring programs to engineering students.
- 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 has continued to pursue its current EPO program outlined above. To enhance the program and to begin addressing NSO outreach in Hawaiʻi, 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 Hawaiʻi 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: In FY 2010, NSO developed a plan for a partnership program in which NSO will develop formal and informal educational materials for presentation by partners that have existing programs addressing a wide range of audiences. For NSO this would have the effect of providing multiple part-time EPO officers. For the partners it will provide access to current materials and information on solar science tailored to meet different audience needs. As a part of this effort, NSO has applied for a U.S. Service Mark for *Ask Mr. Sunspot*. This has been the name since 1994 of the on-line Q&A forum. It now is the name of the NSO education program. 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. During 2010 this was shown to be highly successful with multiple requests for the 18-ft Sun balloon at schools, parks, and public events.

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 Hawaiʻi 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's Dyer Observatory, the U.S. Space & Rocket Center, Sci-Quest, and Adventure Science.
- **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 Scientifically Connected Communities program sponsored by New Mexico State University and supporting teachers across the state.
- **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/Nashville, Alamogordo, and Las Cruces/Upham and Albuquerque, 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 Solar Optics</u>: HOSO will be based on NOAO's successful HOO program. It will be employed in ATST and with the addition of optics activities available in the Exploratorium Cookbooks and other resources. NSO anticipates employing the services of the HOO staff for one FTE year 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 Hawai‘i 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 Domain II, Strand I: What We Know About the World Around Us, Historical Perspective. 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:

- Need: 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).
- Magnetism: 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.
- Optics: 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.
- Computers. 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.
- Interdisciplinary aspects: 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 underrepresented students 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 joined NSO in summer 2009 and defended his Masters thesis in August 2010 on flare excitation of high-ℓ p-modes based on archived GONG data. In addition, we hired an African-American who received his PhD in physics from Howard University in 2009 has been working at NSO for the past year on 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 2011 PROGRAM IMPLEMENTATION

The ATST construction phase is now in full swing. Several changes in the organization of the NSO staff are allowing us to address the challenges of conducting ATST while still providing support to the solar user community.

7.1 Organization

Figure 7.1 shows the new NSO organizational structure. Major changes include the appointment of Thomas Rimmele as Associate Director to manage the ATST tasks at Sac Peak, including the Dunn Solar Telescope, which serves as a learning tool for ATST instrumentation and operations. Another major change is the combining of SOLIS and GONG to form the NSO Synoptic Program and the appointment of Frank Hill as Associate Director to oversee that program.

7.1.1 Director's Office

The NSO Director's office consists of the Director, a Deputy Director responsible for overall Tucson operational support, and an Executive Administrative Manager; it also receives financial and budget support from the NSO/SP-ATST Facilities and Business 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 Tucson and McMath-Pierce operations. 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 is undertaking several ATST work packages. 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. Thomas Rimmele has moved 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 is now the DST Program Scientist and Craig Gullixson the DST Project and Telescope Manager, replacing Steve Hegwer who is now the ATST Instrument Engineer. Rex Hunter has the dual role of NSO/SP Infrastructure/Business Manager and ATST Business Manager. To make this possible, Ramona Elrod has assumed some of his responsibilities at Sac Peak and reports directly to him. Rex Hunter is responsible for buildings and grounds, administration and business functions. Rimmele and Hunter report to the NSO Director.

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 NSO Deputy Director has overall responsibility in Tucson. Priscilla Piano is the Administrative Manager as well as Executive Assistant to the Director. McMath-Pierce (McMP) 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 and NSO SOLIS are being combined into a single NSO Synoptic Program that will be led Frank Hill, who will become the Associate Director for Synoptics. We have approached the merger in multiple steps, starting with data handling and processing. The technical staff working for SOLIS and GONG and supporting the McMP will be combined into a centralized engineering staff under Kim Streander.

The Deputy Director will head a Project Resource Allocations Committee made up of representatives from the various NSO programs.

7.1.4 NSO ATST

NSO ATST has been funded primarily by the ATST Design and Development (D&D) grant 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, staffing has been ramped up with lead engineers taking responsibility for the various work packages. Some of the NSO personnel have transferred full time to ATST construction while others are working part time for the project.

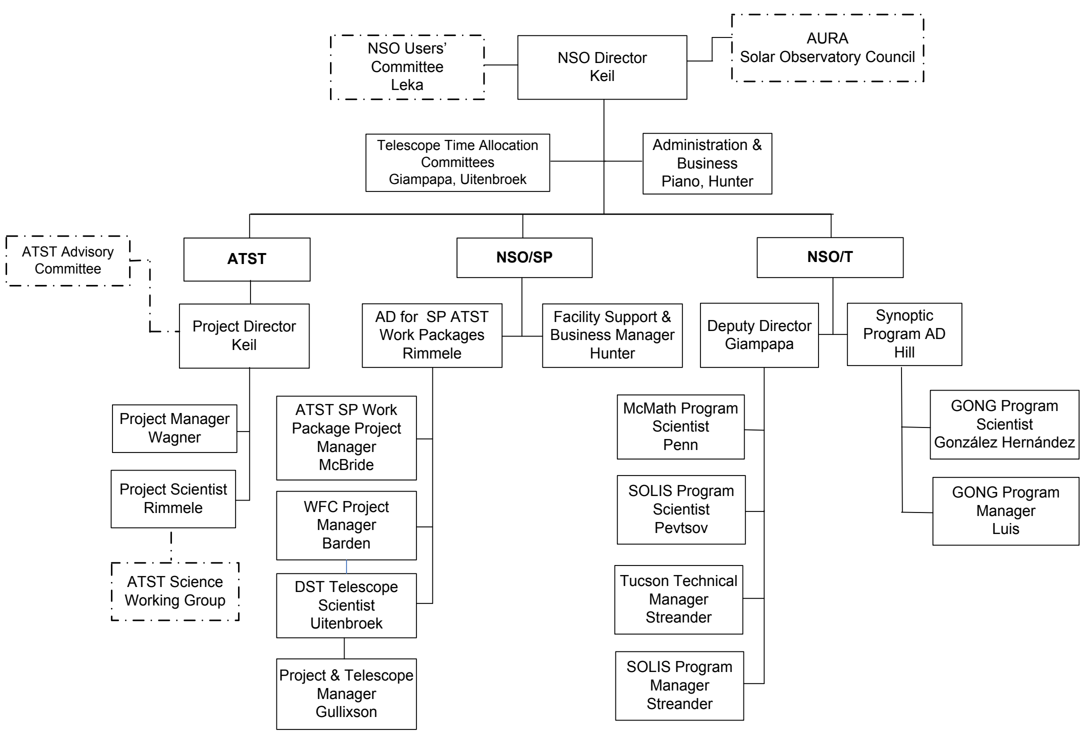


Figure 7.1. *NSO Transitional Period Organizational Chart*

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 can be beneficial to the growth of the solar research community. NSO will also move a part of its work force to Maui in addition to new hires on Maui to operate the ATST.

7.2.1 NSO Directorate Site Solicitation

The Association of Universities for Research in Astronomy, Inc. (AURA) has solicited proposals to serve as the host site for the National Solar Observatory. Final proposals are due December 30, 2010. Eligible institutions include universities or consortia of institutions that include at least one university in their membership. The principal objective of the solicitation is to achieve the consolidation of respective NSO scientific staff presently located at Sunspot, New Mexico and in 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 NSO and the host organization that will lead to an increase in the number and diversity of faculty and students in solar physics research and education and closely related fields.

The solicitation called for pre-letters of intent that were due in March 2010. This was followed by briefings in Sunspot and Tucson to provide potential proposers with a firsthand look at NSO and NSO operations, and to provide a common forum during which additional information about the NSO was provided and questions addressed. Attendance at the briefings were at the expense of the participants.

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 prematurely the access to 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 interest of the NSO.

7.2.2 Estimated Costs

The exact costs of establishing a new directorate site location for NSO and operations on Maui are yet to be determined and will depend on many factors including location, proposed support from the host institution, and programs that will be supported in the ATST era. It is worthwhile for future planning, however, to have some rough cost estimates to better understand the magnitude of the required planning. Table 7.2-1 presents some of the cost estimates based on several factors, including the cost of land on Maui, typical building costs, relocation 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 Establish a New NSO Directorate Site & Operations on Maui

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. University proposals to host NSO may include a building that NSO can lease. This would transfer the cost from relocation to operations and can distribute it over many years. NSO will need an operating location on Maui to house administrative staff, computing facilities, engineering and maintenance crews, and an outreach program that is at a suitable location off the Haleakalā summit. This Maui base facility would ideally be at or near the University of Hawaiʻi 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, stipend for temporary housing, travel to Maui, etc.

7.3 FY 2011 Spending Plan

The NSO spending plan is based on receiving the President's FY 2011 budget. Any reductions from this amount will be addressed initially with the NSO Director's reserve funds. Deeper cuts will require program reductions.

7.3.1 Total Budget

Table 7.3-1 summarizes the funding that NSO expects to receive as new NSF funding, as well as anticipated non-grant revenues for support of operations in FY 2011. The NSO program described in Sections 3-6 was developed based on receiving $9,510K of NSF funding for the NSO base program in FY 2011 and an additional $17M of MREFC funding for the ATST. NSO receives additional operational support from the Air Force Research Laboratory, through an MOU between the Air Force and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. NSO will also receive funding from the Air Force Weather Agency (AFWA) for GONG operations, freeing GONG program funds that will be reprogrammed to build up SOLIS. NSO earns revenue from cafeteria, Visitor Center, and housing operations on Sacramento Peak that are used to support their respective functions.

Table 7.3-1. NSO FY 2011 Funding

(Dollars in Thousands)

NSF Astronomy Division Funding	9,510
AFRL Support for Sac Peak Operations	400
AFWA Support for GONG Operations	740
NSF REU/RET Program	132
Revenue (Housing, Kitchen, Visitor Center)	176
Programmed Indirects/Carryover	35
ATST Fellowship Support	100
Total NSO Funding	**11,093**

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.

Table 7.3-2 NSO Grants and Contracts

Proposal Title	*Source*	*Term*	*PI*	*Program*	*FY 2011[a]*	*Total Grant [a]*
Proposal to NSF International Research Experiences for Students	NSF/IRES	2010-2012 (3 yrs.)	Hill/Jain	GONG	50,000[b]	150,000[b]
A Next Generation Model of the Corona and Solar Wind	NASA sub-award via SAIC	2007-2011 (4 yrs.)	Harvey	SOLIS	15,200	60,832
3D Magnetic Fields: The Dynamic Scaffold of the Solar Atmosphere	NASA	2008-2011 (3 yrs.)	Harvey/Norton	SOLIS	125,737	400,452
Incorporation of a Generalized Data Assimilation Module within a Global Photospheric Flux Transport Model	AFOSR	2007-2010 (3 yrs.)	Harvey/Henney	SOLIS	28,515	55,129
Data Services Upgrade for SOLIS/VSM Stokes Profile Data	NASA	2010 (1 yr.)	Harvey/Henney	SOLIS	46,347	46,347
A Study of Seismic Signatures of Active Regions in Farside Imaging for Applications to Space-Weather	NASA	2008-2010 (3 yrs.)	Hill	GONG	119,281	319,408
Helioseismic Studies with MDI	NASA GIP	2007-2011 (4 yrs.)	Hill	GONG	262,533	753,601
Observing Support at the McMath-Pierce Solar Telescope	NASA	2007-2011 (4 yrs)	Giampapa	McMP Observing	23,572	46,860
Solar Magnetic Fields during a Deep Minimum of Solar Cycle	NASA	2009-2011 (2 yrs.)	Pevtsov		180,125	360,811
Hinode Support (Sac Peak collaboration w/ Lockheed)	NASA sub-award via Lockheed	2008-2010 (3 yrs.)	Rimmele/Uitenbroek	Hinode Support	107,723	323,170
A Facility for High-Resolution Spectroscopy: Laboratory and Ground-based Observations in Support of Upper Atmospheric Research	NASA UARP	2009-2012 (3 yrs.)	Giampapa	McMath-Pierce FTS	109,308	337,859
Adding Hα to the GONG Instruments as a Backup System for the AF Weather Agency's O-SPAN Space Weather Network	AFOSR	2009-2011 (3 yrs.)	Hill	GONG	760,400	1,378,225
Development of the Virtual Solar Observatory (VSO)	NASA	2009-2011 (3 yrs)	Hill	VSO	118,821[c]	413,972[d]
Support for the Improved Solar Observing Optical Network (ISOON) at NSO/SP	AFOSR	2009-2011 (2 yrs)	Radick/Keil	ISOON	65,585	65,585
Support for Evans Solar Facility	AFOSR	2010-2011 (1 yr.)	Radick/Keil	ESF	28,910	28,910
				TOTAL	**2,042,057**	**4,741,161**

[a] *Amounts do not include NSF fee.*

[b] *NSO fee not assessed.*

[c] *Does not include sub-awards to Stanford U., Harvard-SAO, & Montana State each year, as well as NSF fee.*

[d] *Actual grant total, including sub-awards less NSF fee: $848,901.*

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 broken down further 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 supported by the NSF FY 2011 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.

Table 7.3-3. NSO Spending Plan

(Dollars in Thousands)

	Director's Office	Sunspot	Tucson			TOTAL
				Synoptics		
Expenses			McMP	GONG	SOLIS	
Director, Staff, Committee support	434					434
Directorate Site Development	**16**	6				22
Scientific Staff		728	159	990	567	2,444
Scientific Support/Computing		364	54	726	654	1,798
Instrument Development		938	194	290	507	1,929
Maintenance/Telescope Operations		348	214	677	253	1,492
Facilities		681				681
Administrative Support		239	99	201	66	604
Educational & Public Outreach[1]	111	163	66			339
NOAO Business Support[2]	46	176	157	274	215	869
ATST Fellowship[3]		150				150
AURA Management Fee	330					330
Program Total	**937**	**3,793**	**943**	**3,158**	**2,262**	**11,093**
Revenue						
Programmed Indirects/Carryover	(24)	0	0	(11)		(35)
Housing Revenue		(104)				(104)
Meal Revenue		(17)				(17)
NSF REU/RET Funding		(66)	(66)			(132)
Air Force Support		(400)		(740)		(1,140)
ATST Fellowship Support		(100)				(100)
Visitor Center Revenue		(55)				(55)
NSF/AST Funds	**913**	**3,051**	**877**	**2,407**	**2,262**	**9,510**

[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 in Tucson.*

[3] *AURA provides support for cost sharing of an ATST Fellowship.*

Figures 7.3-1 and 7.3-2 show graphically 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 into a single program, we will achieve some economy of scale, allowing us to use funds normally allocated to GONG operations for ramp up of SOLIS and ATST operations as outlined in NSO's Long Range Plan.

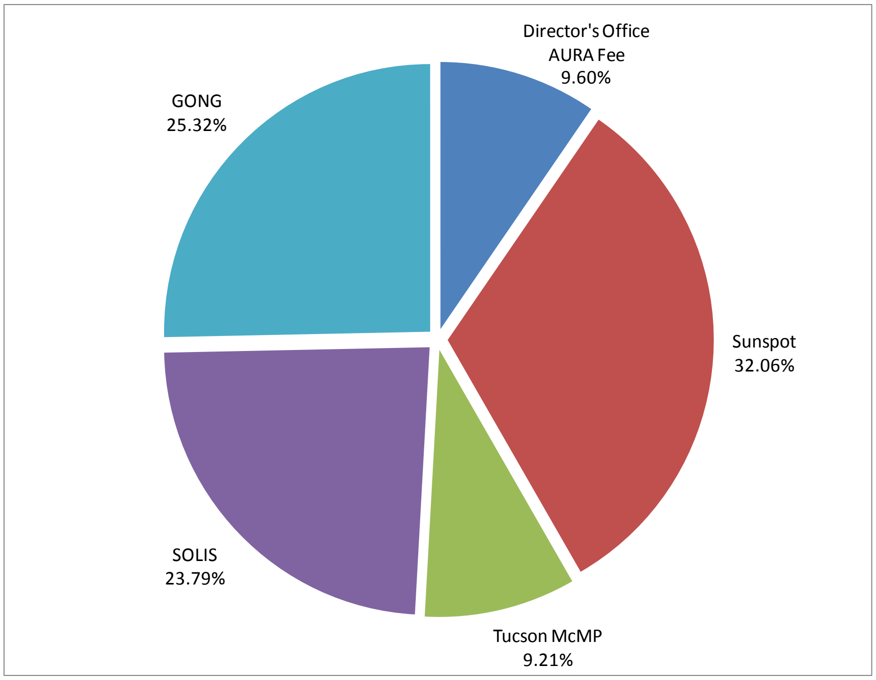


Figure 7.3-1. *Distribution of FY 2011 budget by functional area.*

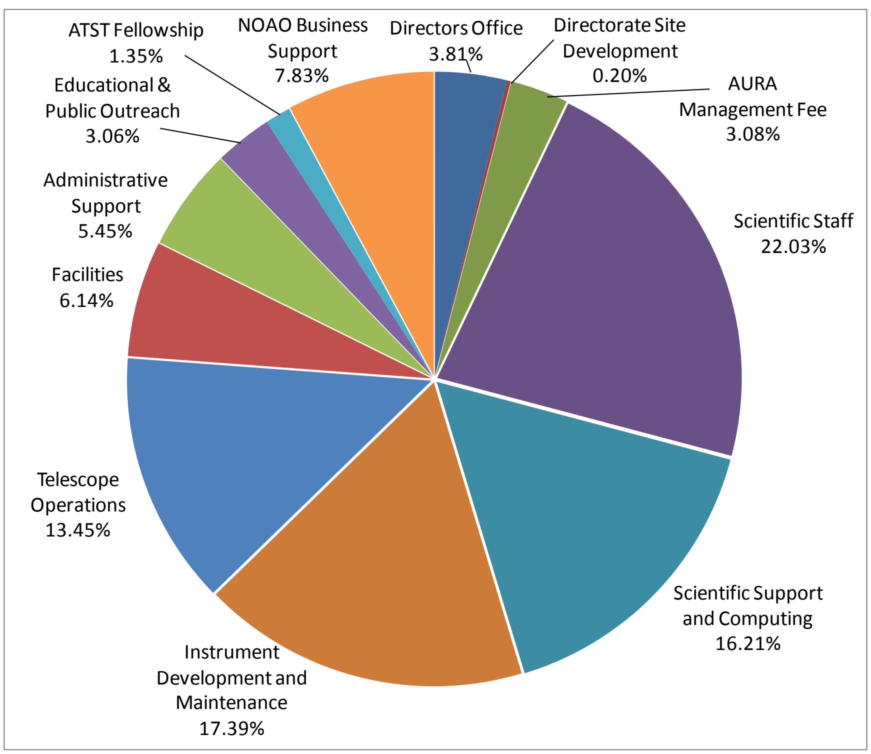


Figure 7.3-2. *Distribution of NSO budget by tasks.*

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	1.9	376	29	405
Committees			9	9
Directorate Site Development	0.1	16		16
NOAO Support		32	14	46
AURA Management Fee			342	342
Reserve			9	9
Outreach Support from NOAO		77	33	111
Total Director's Office	**2**	**$501**	**$436**	**$937**

Table 7.3-4 presents the Director's office budget. As seen in Table 7.3-1, $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 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	151	8	159
Science Support/Computing	0.4	41	13	54
Instrument Development	1.85	169	25	194
Telescope Operations	1.70	187	27	214
Administration	0.48	94	5	99
NOAO Support		110	47	157
Outreach (REU/RET)		53	13	66
Total Tucson/McMP	**5.53**	**$805**	**$137**	**$942**

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.

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

Table 7.3-6. NSO/SOLIS

(Dollars in Thousands)

	FTEs	*Payroll*	*Non-Payroll*	*Total*
Scientific Staff	4.6	539	27	567
Software Support	5.6	600	54	654
Instrument Development	4.15	471	36	507
Telescope Operations	2.3	138	115	253
Administration	0.32	63	3	66
NOAO Support	0	151	65	215
Total SOLIS	**16.97**	**$1,963**	**$300**	**$2,263**

Table 7.3-6 shows a substantial increase in SOLIS operational funding during FY 2011. This increase includes using GONG savings due to Air Force funding to hire postdoctoral research fellows to work on SOLIS science, and programming support for the SOLIS 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 Integrated Sunlight Spectrometer spectra.

Instrument development is aimed at upgrading the VSM cameras and modulators and completing the full-disk patrol imager.

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

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

Table 7.3-7. NSO/GONG

(Dollars in Thousands)

	FTEs	*Payroll*	*Non-Payroll*	*Total*
Scientific Staff	7.5	960	30	990
DMAC Operations	7.0	599	127	726
Instrument	1.5	162	128	290
Telescope Operations	4.5	378	299	677
Administration	2	191	10	201
NOAO Support		219	55	274
Total GONG	**22.5**	**$2,510**	**$649**	**$3,159**

Table 7.3-7 summarizes the GONG spending plan for FY 2011. Although the table does not show an outreach line, the GONG scientific staff participate in the outreach program at Tucson and receives support from the NOAO outreach line shown in the Director's office budget. The table contains the $740K of Air Force funds which covers most of the site operations and some data handling.

The GONG scientific staff includes a GONG Program Scientist who leads the program and reports to the Synoptic Associate Director. The 7.5 FTEs include an 0.5 FTE Instrument Scientist. The remaining 7.0 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 members collect, process, and distribute the GONG data.

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 Manger who manages the GONG program and reports to the GONG Program Scientist and an administrative assistant.

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

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 ATST postdoctoral positions that are cost-shared with AURA.

Table 7.3-8. NSO/SP

(Dollars in Thousands)

	FTEs	*Payroll*	*Non-*	*Total*
Scientific Staff	5.1	688	40	728
Directorate Site Support	0.1	6	0	6
Science Support/Computing	3.5	249	115	364
Instrument Development	17.5	744	194	938
Telescope Operations	4.15	322	26	348
Facilities	5	282	398	681
ATST Fellowship	1.5	150	0	150
Administration	3.4	215	24	239
NOAO Support	0	141	35	176
Outreach (REU/RET),	2	114	49	163
Total NSO/SP	**42.3**	**$2,911**	**$881**	**$3,793**

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 7.3-8 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 U.S. AF 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 2011 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, which is the NSO's top priority. Now that construction funding has begun, the NSO base program must be organized to anticipate the operations and programs NSO will conduct in the ATST operations era. These include the ATST and a synoptic program, as well as a continuation of the robust NSO instrument development program. Ongoing support at current telescopes and instrument projects are designed to contribute to the scientific and technical programs for the ATST. NSO staff on NSF base support will continue to work toward ATST operations planning and to develop 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. Staff on synoptic programs will work toward a synoptic network that includes vector magnetometry and multi-wavelength imaging as well as enhanced techniques for examining subsurface solar structure.

7.5 Infrastructure Plan and Strategic Needs

With the commissioning date and scientific operation of the Advanced Technology Solar Telescope about seven years away, NSO must continue to serve the U.S. solar community with its current facilities and maintain them 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 on line 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*

During FY 2010, NSO initiated a number of infrastructure upgrades. Several of these are now complete and the remainder should be completed by the end of FY 2011.

Table 7.5-1 ARRA Funded Infrastructure Improvements

Item	*Cost*	*Description*	*Status*
DST Deformable Mirror (DM) Replacement	$180,000	Replace old AO mirror.	New DMs & electronics purchased; installation in progress.
Sac Peak Road Maintenance	$200,000	Maintenance/Safety.	Contract awarded; scheduled for completion in fall 2010
SOLIS Tower Clamshell Hydraulic Rams	$80,000	Replace failing hydraulic system.	Completed .
McMP Telescope Control System	$75,000	Upgrade to modern control system.	Bids received.
McMath-Pierce Glycol Inspection/Maintenance	$30,000	Safety – Replace corroded pipes.	Completed.
GONG Network Site Workstations	$81,000	Replace site workstations purchased in 1999.	Completed.
Synoptic Data Processing	$68,000	Increase capacity of data management and archive to handle SOLIS and real-time GONG data.	Hardware received; integration into existing system in progress; scheduled for completion in Feb. 2011.
DST Basic Infrastructure Needs	$225,000	Upgrade/replace old equipment; improve safety.	Electrical network completed; elevator evaluated.
McMP CCD Camera	$35,000	Upgrade to modern CCD.	Camera & software received; integration in progress and scheduled for completion in Jan. 2011
McMP Enclosure Clean and Paint Interior	$60,000	Maintenance; decrease dust.	Bids received; work scheduled for completion by Jun. 2011.
NSO/SP Workstation Upgrade	$62,000	Allow rapid reduction of large data sets and modeling.	Workstations received.
NSO/SP Local Area Network	$170,000	Upgrade LAN to handle increased data processing	In progress
NSO/SP Server Upgrades	$50,000	Replace obsolete equipment to handle increased data flow.	In progress
GONG Real-Time Data Transfer	$84,000	Real-time transfer of full resolution GONG data.	In progress
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 a safe and efficient operation 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.

7.5.2 Infrastructure Improvements Accomplished with FY 2010 Base Funding

In addition to our normal maintenance program, several infrastructure projects were completed with base funding in FY 2010.

NSO/Tucson

Status of 2010 base-funded infrastructure upgrades for SOLIS and the McMP on Kitt Peak:

- Purchase of a spare for the SOLIS system area network (SAN) on Kitt Peak to remove single point of failure. *Completed.*
- Purchase of a spare CPU for the SOLIS observing room to remove single point of failure. *Completed.*
- Upgrade of McMP network switch to handle increased data load. *Completed.*
- Purchase electronic data logging equipment to improve troubleshooting capability. *Completed.*
- Purchase of binocular microscope zoom and camera guiding system. *Completed.*
- Upgrade of the McMP/SOLIS UPS to a larger capacity. *Under review by Kitt Peak mountain electricians.*
- Purchase of a mountain based vehicle for SOLIS/McMP personnel to transfer equipment. *Deferred. Depending on priorities, will be considered for purchase in FY 2011.*
- Purchase of replacement tools and tooling for the McMP machine shop and SOLIS. *In process. Inventory has been completed and equipment identified for replacement.*
- Patch and seal the concrete at the top of the McMath-Pierce to prevent further deterioration and damage. *Deferred to ARRA funded project.*
- Replacement of obsolete desktop PC system for McMP visiting astronomers' use. *Awaiting funding approval*
- Replacement of McM-P #2 Mirror Hot Air Dispersal System to improve seeing. *Deferred until engineering tests result in finalizing design parameters.*

NSO/SP

Status of 2010 base-funded infrastructure upgrades at Sac Peak:

- DST Dust Remediation – Complete project with final concrete work. *On-going project. Further progress was made in FY10 on pouring concrete in DST furnace room and new ducting for air return.*
- Housing – Renovate two to three relocatable houses, including new paint, plumbing fixtures and flooring where necessary. *This is an on-going project. In FY10, two houses were renovated for new residents. At least two additional houses are scheduled for renovation in FY11.*
- Exterior painting of Hilltop Dome, Evans Solar Facility and visitor apartments. *Exterior painting was started at the Hilltop and will continue in FY11. Other facilities to follow.*

- Renovation of Director's and ISOON offices, including painting, lighting upgrades, new window coverings. *Project not feasible in FY10 due to* lack of *manpower availability.*
- Replacement of onsite staff vehicle (Ford Taurus Wagon) with new or used Minivan or Wagon. *Did not have the budget to replace this vehicle in FY10. Depending upon priorities, we will try to in FY11.*
- Purchase of liquid nitrogen compressor.
  Deferred. Re-evaluating priority based on need and cost.
- Replacement of commercial lawn mowing equipment.
  Deferred. Will reevaluate in spring 2011.

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APPENDICES

APPENDIX A. OBSERVING & USER STATISTICS

APPENDIX B. ORGANIZATIONAL PARTNERSHIPS

APPENDIX C. PUBLICATIONS

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APPENDIX F. BUDGET & STAFFING

APPENDIX G. SCIENTIFIC STAFF RESEARCH & SERVICE

APPENDIX H. ACRONYM GLOSSARY

APPENDIX A: OBSERVING AND USER STATISTICS
(October 1, 2009 - September 30, 2010)

In the 12 months ending 30 September 2010, 68 observing programs, which included 16 thesis programs, were carried out at NSO. Associated with these programs were 61 scientists, students, and technical staff from 25 U.S. and foreign institutions.

NSO Observing Programs by Type (US and Foreign)

12 Months Ended September 2010	Nbr	% Total
Programs (US, involving 1 non-thesis grad student)	42	62%
Programs (non-US)	10	15%
Thesis (US, involving 4 grad students)	11	16%
Thesis (non-US, involving 8 grad students)	5	7%
Total Number of Unique Science Projects*	**68**	**100%**

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

Users of NSO Facilities by Category

	Visitors				NSO/NOAO Staff
	US	Non-US	Total	% Total	
PhDs	22	19	41	67%	13
Graduate Students	3	16	19	31%	0
Undergraduate Students	1	0	1	2%	0
Other	0	0	0	0%	19
Total Users	**26**	**35**	**61**	**100%**	**32**

Institutions Represented by Visiting Users**

	US	Non-US	Total	% Total
Academic	9	11	20	80%
Non-Academic	3	2	5	20%
Total Academic & Non-Academic	**12**	**13**	**25**	**100%**

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

Institutions Represented by Users

Foreign Institutions (13)

Armagh Observatory, Ireland, UK
INAF - Arcetri Astrophysical Observatory, Italy
Instituto de Astrofisica de Canarias, Spain
Institute of Plasma Physics, Czech Republic
Katholieke Universiteit Leuven
Kiepenheuer Inst fuer Sonnenphysik
Max-Planck Institute for Solar System Research
Queen's University, Ireland, UK
University of Cologne
Universidad de Monterrey, Mexico
University of Nice-Sophia Antipolis
University of Sheffield, UK
Utrecht University

US Institutions (12)

California State University, Northridge
Dickinson College
Edinboro University
Harvard Smithsonian Center for Astrophysics
University of Arizona
University of California, Berkeley
Unviersity of Florida
University of Hawaii, IfA
University of Maryland, Baltimore County
High Altitude Observatory, NCAR, Boulder
NASA/Ames Research Center
NASA/Goddard Space Flight Center (NASA/GSFC)
NASA/Langley Research Center
US Air Force/Philips Lab (USAF/PL/GSS)

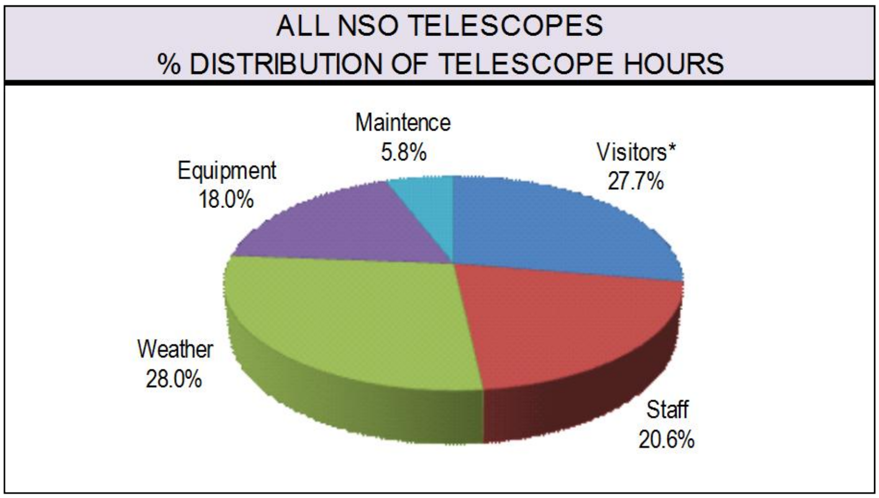
Number of Users by Nationality

Belgium	1	Italy	2
Czech Republic	1	Mexico	1
England, UK	2	Netherlands	8
France	2	Spain	3
Germany	6	Switzerland	1
Ireland, UK	8	United States	58

FY 2010 USER STATISTICS – TELESCOPE USAGE AND PERFORMANCE DATA

In the fiscal year ending 30 September 2010, 27.7% of the total available telescope hours at NSO/Sacramento Peak and NSO/Kitt Peak went to the observing programs of visiting principal investigators; 20.6% were devoted to those of NSO scientists. Scheduled maintenance (including instrument tests, engineering, and equipment changes) accounted for 5.8% of total allotted telescope hours.

Total "downtime" (hours lost to weather and equipment problems) for NSO telescopes was 46.0%. A significant portion of these lost observing hours were due to bad weather (28.0%), with 18.0% lost to equipment problems.



NSO TELESCOPES
Percent Distribution of Telescope Hours
(Scheduled vs. Downtime)
01 October 2009 - 30 September 2010

Telescope	Hours Scheduled	% Hours Used By:		% Hours Lost To:		% Hrs. Lost To:
		Visitors[a]	Staff	Weather	Equipment	Scheduled Maintenance
Dunn Solar Telescope/SP	3,648.0	27.5%	18.3%	31.4%	1.4%	21.3%
McMath-Pierce*	4,687.0	16.0%	41.5%	25.6%	16.9%	0.0%
KP SOLIS Tower[a,b]	2,876.0	57.6%	6.8%	28.4%	7.2%	0.0%
FTS Lab[c]*	1,368.0	0.0%	0.0%	0.0%	99.6%	0.0%
Evans Solar Facility	1,041.0	34.4%	0.0%	61.9%	3.7%	0.0%
Hilltop Dome	0.0	0.0%	0.0%	0.0%	0.0%	0.0%
All Telescopes	**13,620.0**	**27.7%**	**20.6%**	**28.0%**	**18.0%**	**5.8%**

[a]*Includes 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).*

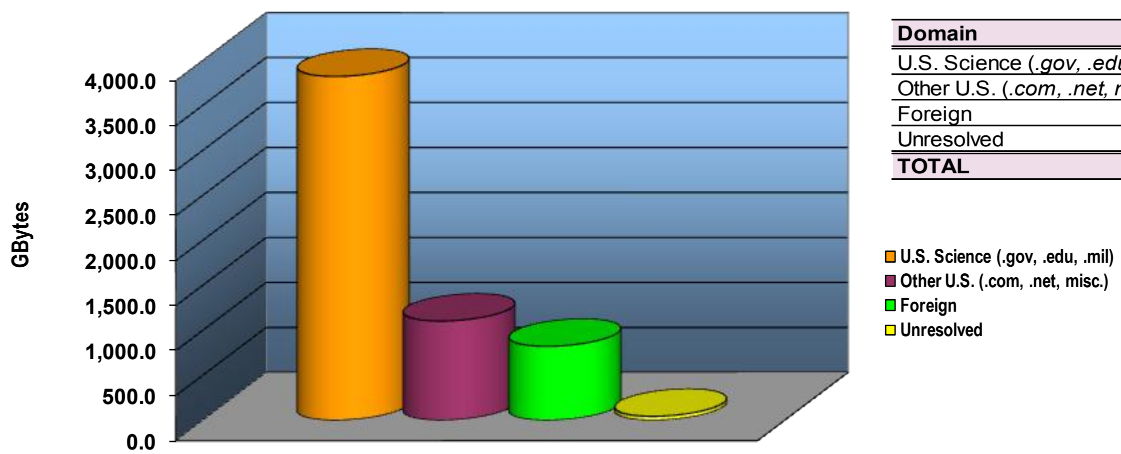
[c]*The Fourier Transform Spectrometer has been subject to repairs through most of the fiscal year.*

FY 2010 USER STATISTICS – ARCHIVES & DATA BASES

(October 1, 2009 - September 30, 2010)

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 2009 - 30 September 2010



Domain	Gbytes
U.S. Science (*.gov, .edu, .mil*)	3,820.0
Other U.S. (*.com, .net, misc.*)	1,101.5
Foreign	820.8
Unresolved	43.1
TOTAL	**5,785.3**

PRODUCT DISTRIBUTION BY DOWNLOADED GBYTES
01 October 2009 - 30 September 2010

Site	Product Type	Gbytes	%
T	GONG Helioseismology	2,946.71	55.3%
T	GONG (Magnetograms, spectra, time series, frequencies)	636.63	12.0%
T	SOLIS/VSM	498.03	9.3%
SP & T	Other	455.29	8.5%
SP	Realtime Images and Movies (*OSPAN, Other)*	317.26	6.0%
SP	SMEI Experiment & Data Pages	171.46	3.2%
T	KPVT (magnetograms, synoptic maps, helium images)	120.07	2.3%
SP	General Information	48.81	0.9%
T	FTS (Spectral atlases, general archive)	36.60	0.7%
SP	Press Releases	36.29	0.7%
SP	Staff Pages	26.28	0.5%
T	Evans/SP Spectroheliograms (Hα, Calcium K images)	11.21	0.2%
SP	Adaptive Optics Pages	5.63	0.1%
SP	Telescope Home Pages	5.63	0.1%
SP	Icon & Background Images	5.01	0.1%
SP	Corona Maps & Other Images	2.50	0.0%
SP	Public Relations	1.88	0.0%
SP	OSPAN Project Pages	1.88	0.0%
TOTAL		**5,327.17**	**100.0%**

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 and multi-conjugate 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, AFRL, 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 (0.75 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 2009 through September 2010)

Author—NSO Staff **Author**—REU
Author—RET Author—Grad Student
Author—Non-REU Undergrad

Refereed Publications

1. Balasubramaniam, K.S., Cliver, E.W., **Pevtsov, A**., Temmer, M., Henry, T.W., Hudson, H.S., Imada, S., Ling, A.G., Moore, R.L.; Muhr, N., Neidig, D.F., **Petrie, G.J.D.**, Veronig, A.M., Vršnak, B., White, S. M. 2010, "On the Origin of the Solar Moreton Wave of 2006 December 6," ApJ, **723**, 587-601.

2. Balbus, S.A., Bonart, J., Latter, H.N., Weiss, N.O. 2010, "On Differential Rotation and Convection in the Sun," MNRAS, (in press).

3. Beck, C., **Tritschler, A.**, **Wöger, F.** 2010, "A Chromospheric Dark-Cored Fibril in Ca II IR Spectra," Astron. Nachr., **331**, 574-576.

4. Beck, C., Bellot Rubio, L.R., Kentischer, T.J., **Tritschler, A.**, and Del Toro Iniesta, J.C. 2010, "Two-Dimensional Solar Spectropolarimetry with the KIS/IAA Visible Imaging Polarimeter," A&A, **520**, A115.

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8. Brun, A.S., Antia, H.M., Chitre, S.M. 2010, "Is the Solar Convection Zone in Strict Thermal Wind Balance?," A&A, **510**, id.A33.

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11. Chaplin, W.J. et al. (including **R. Howe)** 2009, "Kepler Observes Oscillations in Solar-Type Stars," ApJ Letters (in press).

12. Chaplin, W.J. et al. (including **M. Giampapa** & **R. Howe**) 2010, "The Asteroseismic Potential of Kepler: First Results for Solar-Type Stars," ApJ Letters, **713,** L169-L175.

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15. Crockett, P.J., Mathioudakis, M., Jess, D.B., Shelyag, S., Keenan, F.P. and Christian, D.J. 2010, "The Area Distribution of Solar Magnetic Bright Points," ApJ Letters, **722**, L188-L193.

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22. **González Hernández, I., Howe, R., Komm, R.,** and **Hill, F.** 2010, "Meridional Circulation during the Extended Solar Minimum: Another Component of the Torsional Oscillation?" ApJ Letters, **713,** L16-L20.

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APPENDIX D: MILESTONES FY 2011

This section describes the major project milestones for 2010.

D1. Advanced Technology Solar Telescope

- *Conduct ATST safety review.*
- *Hold an NSF-conducted baseline review.*
- *Obtain the Conservation District Use Permit for Construction on Haleakalā.*
- *Complete the Special Use Permit (SUP) for using the Haleakalā National Park (HNP) Road.*
- *Obtain the lease with the University of Hawaii.*
- *Conduct ground breaking ceremony.*
- *Initiate and manage site work on Haleakalā.*
- *Manage vendor construction contracts for the major sub-assemblies (M1 blank, enclosure, telescope mount assembly, M1 assembly, etc.).*

D2. Solar Adaptive Optics

- *Continue MCAO development at the DST*
- *Develop the large format AO system for BBSO's 1.5 m 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

- *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 (synoptic and user-requested) 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 alternative inversion techniques.*
- *Establish transform functions between SOLIS (magnetic field and non-magnetic) measurements and other synoptic type instruments (SOHO/MDI, GONG, ISOON). Conduct comparative studies of SOLIS/VSM measurements of chromospheric fields with other instruments (e.g., SPINOR).*
- *Incorporate robust method of rejection of bad data for the ISS.*
- *Develop unified approach in producing SOLIS synoptic maps on the basis of GONG pipeline code. Add error estimates to magnetic synoptic maps.*
- *Develop software for handling FDP raw data (Level 0) and reduction to Level 1 data.*
- *Integrate FDP and guider 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 space borne coronal data (STEREO, SDO/AIA, Hinode) to calculate and compare energy budgets for coronal fields and CMEs.*
- *Develop robust approach for producing helicity maps based on VSM vector magnetograms.*
- *Investigate usability of chromospheric synoptic maps as a source field for coronal field/interplanetary field extrapolation and solar wind studies.*
- *Start providing digital He10830 data to the community.*
- *Purchase and begin testing the modulator from Meadowlark.*

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

Complete. See Appendix E.

D6. GONG

- *Finish deployment of H-alpha instruments to the sites and support AFWA needs. Set up H-alpha archive.*
- *Increase bandwidth at Learmonth.*
- *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. In particular, continue development of a distributed flare predictor system based on subsurface vorticity and located at the remote sites.*
- *Begin development of SOLIS/Full-Disk Patrol data reduction pipeline (Note this is a Synoptic Program milestone)*
- *Integrate GONG & SOLIS magnetic field synoptic map production. Develop new methjod of creating maps. (Note this is a Synoptic Program milestone)*
- *Replace workstations at the sites. Begin studies to replace the cameras*
- *Implement improved fire safety systems at the sites.*

D7. Virtual Solar Observatory

- *Implement spatial search capability.*
- *Improve catalog searches.*
- *Implement usage reporting system.*
- *Develop interfaces for C and Matlab*
- *Place digitized Sac Peak H-alpha & Ca K images on-line and in VSO.*
- *Place ISOON data in VSO.*

D8. NSO Array Camera (NAC)

- *Identify and purchase 3-5 micron polarization optics.*

D9. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- *Continue to operate SPINOR as a user instrument.*

D10. Facility IR Spectropolarimeter (FIRS)

- *Continue to operate as a user instrument.*

D11. Dunn Solar Telescope Control and Critical Hardware (Systems Upgrade)

- *Complete new motion control for DST mechanisms.*

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

- *Evaluate options for integrating ROSA into the DST data handling system and making the system observer friendly.*
- *Release instrument to the community.*

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

- *Implement a 2D translating limb-guider system.*
- *Develop the control and interface software.*
- *Test and refine the precision pointing algorithms and ephemeris.*

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

- *Continue to operate as a user instrument.*

D15. McMath-Pierce High-Speed, Large-Format Camera System (ARRA Funded Project)

- *Test and integrate the visible light detector for the McMath-Pierce Telescope to complement the IR spectrographic program.*

D17. Establish NSO Headquarters

- *Review of submitted proposals by NSO Consolidation/Relocation Review Panel*

APPENDIX E: STATUS OF FY 2010 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2010 Program Plan. (FY 2010 milestones appear in italics below.)

E1. Advanced Technology Solar Telescope

- *Complete establishment of the Project Management Control System (PMCS).*
  A Sr. Project Controls Specialist is part of the construction team and the PMCS is in full operation.

- *Establish vendor construction contracts for the major sub-assemblies (enclosure, telescope mount assembly (TMA), M1 blank, phase-2 Architecture and Engineering (A&E), etc.) as approval and funds become available.*
  The phase-2 Architecture and Engineering (A&E), M1 Blank, and Enclosure are under contract. The TMA source selection process is well underway and the M1 Assembly RFP is out.

- *Obtain the conservation district use permit for construction on Haleakalā*
  The Conservation District Use Permit Application (CDUA) was submitted by the University of Hawai'i and the associated public meeting is scheduled for August 2010.

- *Complete the Special User Permit (SUP) for using the Haleakalā National Park (HNP) Road.*
  An interim SUP is in place with the HNP and the construction SUP terms are being documented with the HNP towards finalization in parallel with the CDUA process.

E2. Solar Adaptive Optics

- *Continue MCAO development at the DST,*
  In progress.

- *Develop the large format AO system for BBSO's 1.5 m as a proof of concept for ATST.*
  In progress.

- *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 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.*

This project is currently stalled. A staff scientist has not been assigned to the project for defining requirements and processes and to oversee testing and evaluation. In addition, use of the DLSP has been limited. Currently, most customers for DST data are using the *Hinode* spectro-polarimeter (SP), which has very similar optics and is not perturbed by seeing. We concentrate on instruments that provide alternative spectral diagnostics to the Fe I 6302 line pair that is covered by *Hinode* SP and the DLSP alike.

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.*

  Observations continue on a daily basis with data being distributed to the community. New synoptic chromospheric data charts are being generated and the NSO synoptic data pipeline is undergoing testing and comparison with existing processing routines. We have started a community-wide discussion with a goal to develop "standard" format for synoptic maps. A splinter meeting is scheduled for July 28, during the SHINE meeting in Santa Fe, NM. A follow-up working group meeting is planned for November/December 2010 in Tucson, AZ.

- *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.*

  On-going. A detailed comparison among SOLIS VSM, GONG, and HMI data was generated in May 2010. Additional comparisons have been done between *Hinode* and the VSM. The second Vector Magnetogram Comparison Workshop has been scheduled for October 19 – 21, 2010 in Tucson. Potential field extrapolation was done using synoptic chromospheric magnetograms. Preliminary comparison of extrapolation results using traditional (photospheric) and new (chromospheric) synoptic maps shows good agreement for some solar rotations, but significant differences for other rotations. Some differences can be explained by the fact that traditional extrapolation schemes use radial field as a boundary condition, but the chromospheric synoptic maps represent line-of-sight (LOS) field. Work is now underway to develop an average correction factor for chromospheric data to do the conversion from LOS to radial field.

- *Install Sarnoff cameras and update analysis software to process new data format.*

The cameras were installed in December 2009 with a period of six months required to get most of the data products back on line. Problems with the calibration unit required substantial correction efforts. There are a few remaining data format problems for the 6302V data that are under investigation. SOLIS scientists are working closely with programmers in developing a systematic approach for resolving the remaining data reduction issues.

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

  Complete. Several data sets are being generated every 10 minutes using 150 scan positions. Fast-scan observations can now be conducted at any time upon observing request.

- *Develop extinction monitor data reduction algorithms and install instrument to monitor atmospheric line-of-sight conditions.*

  Hardware is complete with final alignment tests scheduled within the next few months. Reduction algorithms will start development once hardware is installed.

- *Incorporate ISS data reduction into the SOLIS pipeline.*

  Complete. ISS data are now being reduced within the NSO synoptic pipeline. Level-3 products based on ISS data may still be affected by "bad" data. "Bad" data rejection methods for the ISS are under investigation.

- *Install monitor to record localized seeing conditions in the VSM line of sight.*

  The software is complete with hardware currently at 80% complete.

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

  FDP guider hardware has been installed in the FDP and is undergoing functional testing.

- *Integrate FDP onto the mount at the SOLIS tower.*

  Installation at the SOLIS tower is tentatively scheduled for November/December 2010.

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

  Due to extremely low level of solar activity, no flare events have been captured to date. Fast-scan observations have been tested, and will be repeated upon users' request.

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

  On-going. Low solar activity has restricted the amount of data to compare. VSM vector magnetograms were used to compute non-linear magnetic field and their magnetic energy content.

- *Purchase and begin testing the modulator from Meadowlark.*

  A modulator package on loan from Meadowlark underwent extensive testing with mixed results. Meadowlark agreed to supply another unit for testing in the August/September timeframe, however fabrication scheduling conflicts has delayed delivery.

E5. Kitt Peak SOLIS Tower (KPST) Clamshell Repair and Improvements (ARRA Funded Project)

- *Obtain contract bids.*
  Complete.

- *Repair hydraulic cylinders.*
  Complete.

- *Install hydraulic oil compensator system to account for uneven piston wear over time.*
  Complete.

- *Install hard stops to take load off cylinders when clamshell assembly is open.*
  Complete.
  The system is currently undergoing testing and tuning of the proportional hydraulic system.

E6. 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.*
  Time-distance is still underway. There are plans to incorporate 3D ring inversion when the community is ready for them.

- *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.*
  Polar field estimate research is still underway, and the zero-point pipeline is under construction.

- *Continue development of space weather predictive tools using ring diagrams, the far-side signal, and the high-cadence magnetograms.*
  This is still underway and primarily research driven (i.e., emerging active regions).

- *Begin development of a distributed flare predictor system based on subsurface vorticity and located at the remote sites.*
  Tests on 24-hour merged data are complete, next step is 8-hour single site test

- *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.*
  Udaipur is complete, Learmonth is still underway as there are problems dealing with Telstra (Australian telecommunications company).

- *Complete the development of the U.S. Air Force Weather Agency Hα observing system for deployment in FY 2010.*
  Development completed; deployment is now (October 2010) 85% complete; full deployment will be completed in January 2011. The delay is due to the recent fire at the Udaipur site.

E7. Virtual Solar Observatory

- *Continue spatial search development.*
  Starting up again.
- *Complete installation of SDO data access.*
  Complete
- *Improve catalog searches.*
  Starting up again.
- *Implement usage reporting system.*
  Starting up again.
- *Develop interfaces for C and Matlab.*
  Starting up again.
- *Place digitized Sac Peak H-alpha & Ca Kmages on-line and in VSO.*
  Digitization is proceeding rapidly. Data are not yet on-line, and additional storage needs to be obtained.
- *Place ISOON data in VSO.*
  A RAID system has been ordered and is currently being installed.

E8. NSO Array Camera (NAC)

- *Develop dual-beam polarimetry feed optics for the NAC from 1000-2000 nm.*
  Complete. Several days of data have been taken and data analysis is being done.
- *Identify and purchase 3-5 micron polarization optics.*
  Collaboration with the NJIT Big Bear Solar Observatory New Solar Telescope (BBSO/NST) has been established, but no optics have yet been purchased.
- *Generalize sub-array readout on NAC.*
  Completed. Sub-array readout allows more efficient use of disk space, but doesn't increase camera speed.

E9. 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.*

Level 2 functionality has been implemented and SPINOR has been released as a user instrument. SPINOR's wide range wavelength coverage is being exploited by NSO staff to conduct DST telescope matrix calibrations. Currently under consideration is the hiring of an additional NSO assistant astronomer, or an Interface Region Imaging Spectrograph (IRIS)/*Hinode* postdoc, either of whom might be a good SPINOR scientist candidate.

E10. Facility IR Spectropolarimeter (FIRS)

This joint effort with the University of Hawaiʿi 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.*

  FIRS has been integrated with the SAN and is accessing DST mechanisms via the common services server.

E11. 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 milestone for FY 2010 is to:

- *Complete new motion control for DST mechanisms.*

  Efforts on replacing the CAMAC system has been temporarily interrupted due to DST staff (software engineer and electronics tech) transfers to the ATST project. Both DST positions have now been filled, with the new staff having started just recently. Replacing the functionality of the CAMAC system is still a high priority, but it is expected that it will take some time before the new personnel are familiar enough with the systems to make significant progress on the CAMAC replacement.

  Significant progress is being made, however, on improving other critical systems at the DST. The power service infrastructure on the observing table has been completely replaced using ARRA funds. ARRA funds are also supporting a contract for a thorough engineering evaluation of the DST mobile work platform, looking at system safety and necessary upgrades. The contract for this evaluation is in place and will be executed in December 2010. Network improvements on the observing table for improving the integration of instrumentation with the DST data handling system are also being accomplished.

E12. Rapid Oscillations in the Solar Atmosphere (ROSA) Imaging System

- *Implement data handling system.*

  ROSA has implemented a stand-alone data handling system, and options are being evaluated for integrating ROSA into the DST data handling system and making the system observer friendly.

- *Release instrument to the community.*
  ROSA has not been released to the community yet, pending resolution of the data handling issues. Queens College Belfast is currently fully supporting UK investigator use of ROSA.

E13. McMath-Pierce Telescope Control System (TCS) Upgrade (ARRA Funded Project)

- *Implement a 2D translating limb-guider system.*
  In progress.

- *Specify and design. Conceptual design review January 2010.*
  Complete.

- *Acquire the limb sensors, manufacture the required hardware and assemble.*
  One limb sensor has been purchased for testing, and hardware for stabilizing the table for mounting scanning stages has been fabricated and installed,

- *Interface to the spectrograph rotation encoder, NAC and IRAO fast tip-tilt mirror.*
  Encoder has been installed and interfaced to a new control and display unit.

- *Develop the control and interface software.*
  Under development.

- *Test and refine the precision pointing algorithms and ephemeris.*
  Waiting on hardware testing.

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

- *Operate IFU as a user instrument.*
  Complete. Dr. Thomas Ayres (U. Colorado) observed CO at 2.1 and 4.6 microns at the solar limb and disk center using the IFU, McMP main spectrograph and NAC in May 2009. The instrument performed well and Ayres found the data quite promising. He hopes to have an opportunity to repeat the observations under conditions of better seeing and increased solar activity to allow use of adaptive optics.

E15. McMath-Pierce Glycol Cooling System Inspection and Repair (ARRA Funded Project)

- *Obtain contractor bids for visual and non-evasive testing.*
  Complete.

- *Perform inspection, validate current documentation, and advise on repairs if needed.*
  Complete.

A detailed report was submitted April 2010 concluding that the system is functional with an expected lifetime of at least 5 years.

E16. 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.*
  Detector has been identified and ordered in July 2010, received September 2010, to be tested October 2010.

- *Obtain a relatively fast computer with ample disk capacity to take full advantage of the camera.*
  Complete. Existing computing system meets requirements.

E17. Establish NSO Directorate Site

- *Release call for letters of intention.*

- *Release call for proposals.*
  The call for proposals, including the call for letters of intention, was released and posted on the NSO Web home page (*http://www.nso.edu/*) on February 12, 2010. Eight letters of intent were received on the April 30, 2010 deadline.

- *Hold site visits to NSO and to potential proposers.*
  One-day visits were held at the NSO Sacramento Peak site on May 21, 2010 and in Tucson on July 8, 2010. Questions and answers that were discussed at the respective site visits are posted on the NSO Directorate Site Proposal Solicitation Web site (*http://www2.nso.edu/FAQ_NSO_DirectorateSiteProp.pdf*).

APPENDIX F: NSO FY 2011 STAFFING SUMMARY

(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)

*Walter Allen, Jr., Research Associate

Areas of Interest

Solar Physics, Waves, Supergranulation

Recent Research Results and Plans for Future Research

Walter Allen has been working on wave trapping in supergranulation. This work involves modeling a supergranule as a regular polygonal cylinder. The four-dimensional wave equation is solved with totally reflective boundary conditions at the cylinder sides. The solution has properties that depend on the model supergranule geometry such as size, depth and number of sides. These properties will be compared to three-dimensional power spectra of supergranules obtained from HMI data, and the model adjusted to match the observations as closely as possible. This will place constraints on the geometry of supergranulation, especially the depth, which cannot be measured directly.

As time permits, future work will improve the realism of the model by adding stratification due to gravity, pressure gradients, and magnetic fields to the wave equation. We also want to dynamically evolve the shape of the supergranule. These steps should improve the correlation between the model and the data.

*Luca Bertello, Associate Scientist

Areas of Interest

Solar variability and heliospheric physics, focusing on the investigation of the physical processes leading to the different aspects of solar variability and on the calibration of the observed solar magnetic field to enhance the database that supports the analysis of conditions in the Sun's corona and heliosphere.

Recent Research Results and Plans for Future Research

In a 2010 paper published in *Solar Physics*, Bertello and collaborators at UCLA have introduced a new Ca II K plage and active network index time series derived from the digitization of almost 40,000 photographic solar images that were obtained at the 60-foot solar tower, between 1915 and 1985, as a part of the monitoring program of the Mount Wilson Observatory. Using appropriate proxies, this time series was extended up to date, making this data set one of the longest Ca II K index series currently available, and a major resource for long-term studies of solar variability.

In another paper recently accepted for publication in *The Astrophysical Journal,* Bertello and Peter Sturrock (Stanford University) have shown evidence for a cluster of *r*-mode oscillations in the solar interior. These oscillations identified in solar diameter measurements may originate below the radiative zone, in or near a slowly rotating solar core. Some preliminary results on how different techniques of constructing synoptic maps affect the prediction of the solar wind speed at Earth were presented at the 2010 SHINE workshop in Santa Fe, NM.

Future Research Plans

The main focus of Bertello's research is on improving the quality of current longitudinal and vector magnetic field observations. At present, only longitudinal photospheric measurements of the solar magnetic field are used to produce global maps of the solar surface. These maps are needed to drive numerical models that calculate the structure of the solar corona and inner heliosphere in several space weather programs. Bertello intends to pursue this interest further and employ the capabilities of the SOLIS instrument to produce reliable chromospheric global maps in the Ca II infrared spectral line at 854.2 nm, and use SOLIS vector measurements to remove some of the limitations introduced by scalar observations.

Service

As a data scientist for SOLIS, Bertello's major responsibility is to provide the solar and heliophysics community with high-quality and reliable data. In recent past, he has served on NSF and NASA proposal reviews and has been a reviewer of publications for *The Astrophysical Journal*, and *Solar Physics*.

*Olga Burtseva, Assistant Scientist

Areas of Interest

Local Helioseismology, Solar Activity

Recent Research Results

Burtseva continues to study temporal variations in the amplitudes and widths of high-degree acoustic modes in the quiet and active Sun by applying ring-diagram technique to the GONG+ and MDI Dopplergrams during the declining phase of cycle 23. The increase in amplitudes and decrease in line-widths in the declining phase of the solar activity is in agreement with previous studies. A similar solar cycle trend in the mode parameters is also seen in the quiet-Sun regions but with a reduced magnitude. Moreover, the amplitudes obtained from GONG+ data show long-term variations on top of the solar cycle trend. The results are presented at the GONG 2010/SoHO 24 conference in Aix-en-Provence, France and published in the conference proceedings.

Burtseva also started studying the evolution of magnetic field in flaring active regions using a feature-tracking technique. The YAFTA magnetic feature-tracking algorithm was applied to characterizing the longitudinal field evolution of AR 10930 during the X6.5 flare on 2006 December 6. GONG++ one-minute cadence magnetograms were used to carry out this work. Several distinct magnetic features were identified, their evolution and interaction around the flare time were traced, and their sudden longitudinal flux changes were interrelated during the flare event. This work was presented at 216th AAS meeting in Miami.

Future Research Plans

Burtseva plans to continue analyzing the amplitudes of high-degree solar *p*-modes in the quiet and active Sun to understand what causes the long variations in the *p*-mode amplitudes seen on top of the solar cycle trend. She is also continuing the work on evolution of magnetic field associated with solar flares by tracking magnetic features.

*Michael Dulick, Scientist

Areas of Interest

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

Research

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.

Service

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

Areas of Interest

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. Recent results were presented in the Proceedings of the SPIE.

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.

Service

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 ATST Instrument Scientist, Elmore has created a Polarimetry Working Group that is addressing particular issues related to calibration of the ATST.

Mark S. Giampapa, Astronomer

Areas of Interest

Stellar Dynamos, Stellar Cycles and Magnetic Activity, Asteroseismology

Recent Research Results

In their astrobiology program, Giampapa, postdoc W. Sherry, and E. Craine (GNAT), utilized an automated telescope to investigate photometric variability in selected solar-type stars in the young Pleiades cluster. The nature of the variability is still being characterized but it may arise from powerful white-light flares on these active objects. The radiation and implied energetic particle emissions from these events can be used as input in the investigation of the evolution of young planetary atmospheres for any planets that may be in the so-called habitable zone. In other research, Giampapa continued his collaborative work in support of *Chandra* X-ray observations of ultracool dwarfs. This effort resulted in a publication in *The Astrophysical Journal* with E. Berger (Harvard) et al. on multi-wavelength observations of X-ray, radio and H-alpha in L and M dwarfs as objects exhibiting unique aspects of chromospheric and coronal heating in late-type dwarf stars. In addition, Giampapa was among the authors in the Chaplin et al. paper published in the *The Astrophysical Journal Letters* on *Kepler* observations of *p*-mode oscillations in three solar-type stars.

Future Research Plans

Giampapa and collaborators Vincenzo Andretta (INAF—Naples) and Ansgar Reiners (University of Göttingen) are applying for telescope time to obtain simultaneous observations of the He I triplet lines at 587.6 nm and 1083.0 nm, respectively, in a sample of G and F dwarf stars with detected coronal X-ray emission. When the data are eventually acquired, the results will be used in models previously developed by Andretta and Giampapa to estimate the area coverage of magnetic active regions on Sun-like stars. This is the first important step toward establishing the empirical relationship between rotation and the filling factor of magnetic active regions as a significant constraint for stellar dynamo theory. 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 the ~100 Myr Pleiades cluster. With Eric Craine (GNAT), their current automated telescope is being reconfigured with a new camera to obtain a wider field of view, enabling the simultaneous photometry of more solar-type stars. Giampapa plans to use the SOLIS ISS for long-term studies of the Sun-as-a-star with an initial investigation focusing on line bisector variability. In addition, Giampapa is investigating the application of Fourier techniques to the analysis of SOLIS VSM data.

Service

M. Giampapa is the deputy director for the National Solar Observatory. In this role, he 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, Solar Observatory Council and other committee meetings as appropriate. 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 is the Diversity Advocate for the NSO. His efforts in this role were recognized in FY10 with an AURA Service Award. Giampapa is leading the planning for a Solar Initiatives Workshop in FY11. He is also chairing a NSO Policy Committee to formulate NSO-specific policies in response to a requirement of the new Cooperative Agreement with the NSF. Giampapa 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. Giampapa is an adjunct astronomer at the University of Arizona.

Irene González Hernández, Associate 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 a statistical analysis of three years of far-side maps that 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. The recent extended solar minimum has provided unprecedented data to study the subsurface meridional circulation. González Hernández et al. investigation of the meridional circulation during this extended minimum resulted in the confirmation of an extra component of these flows similar to the torsional oscillation.

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} indices. 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.

González Hernández plans to extend her previous work on the extra component of the meridional circulation and find the relationship, if it exists, with the torsional oscillation as well as the link with the characteristics of the solar cycle.

Service

González Hernández is the GONG program scientist. In this role, she coordinates the scientific needs and outreach of the project as well as proposal submissions for external funds. She participated in the NSO 2009 Research Experiences for Teachers (RET) summer program as mentor to middle-school teacher Helena Freedlund, whose project involved 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

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 data-parallel nature of the problem. Recently, GENESIS results were compared to those from a modified version of the original High Altitude Observatory/Advanced Stokes Polarimeter (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. Recent improvements/upgrades to the genetic algorithm optimization routines hint at more accurate and faster results, from speeding-up the search and convergence time of the genetic algorithm. This work is currently in preparation for submission to *Solar Physics*.

Harker-Lundberg has recently been working on improving the data reduction routines for the SOLIS pipeline. He identified and corrected an issue in the pipeline which affected the line shape of the nearby terrestrial absorption features at 6302 Å, which subsequently had a deleterious effect on proper wavelength calibration. Furthermore, he has developed an improved routine for removing interference fringes introduced in the recorded spectra by the 6302v modulator. The new method is based on digital filtering (as opposed to a fit to a fringe model), and is more robust than the current method. Finally, he is currently working on improvements to the SOLIS VSM "quick-look" vector field, used as an approximation to the true vector field prior to Stokes inversion. The current method uses only Stokes V to estimate the (longitudinal) field strength. As such, neutral lines are very visible in the quick-look field strength, and its use as a proxy for the total field strength is technically limited to purely vertical fields near disc-center. He has been developing and testing alternate quick-look calculations based on the center-of-gravity technique, various weak-field approximations for both longitudinal and transverse fields, and an integral method based on integrated Stokes Q, U, and V profiles.

Future Research Plans

Harker plans to continue developing the GENESIS code, which offers configuration options so 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. Further along these lines, Harker-Lundberg is Co-I on a grant proposal to search for abrupt vector field changes indicative of flaring activity, following the work of G. Petrie and J. Sudol who found permanent changes in the longitudinal field strength following flares. Harker-Lundberg is also a collaborator on a grant proposal to investigate and validate the correlations/differences in various Milne-Eddington inversion schemes, which has the ultimate goal of providing a "standard" M-E inversion scheme to the solar community.

Service
Harker-Lundberg mentored 2010 NSO REU student Jieun Choi jointly with Dr. Bill Livingston. Her project focused on discrimination of different active region structures (umbra, penumbra, plage, faculae, etc.) based solely on analysis of SOLIS VSM spectra, without prior knowledge of the magnetic field vector in these regions. The project involved developing a procedure based on the Stokes Q, U, and V amplitude and area asymmetries, combined with measurement of the Stokes I line-depth and finding satisfactory segmentations of the different structures. Ms. Choi will present the results of this project at the January 2011 AAS meeting in Seattle.

John W. Harvey, Astronomer

Areas of Interest
Solar Magnetic and Velocity Fields, Helioseismology, Instrumentation

Recent Research Results
During FY 2010, J. Harvey worked mainly on SOLIS and GONG instrument development and maintenance. Essentially no time was available for research. However, a brief study of 35 years of NSO magnetic and coronal hole observations directly showed that the open magnetic field in the heliosphere does largely arise from coronal holes. Previously this conclusion was reached only by using potential field modeling of the coronal magnetic field. A pilot study of chromospheric magnetograms was done in which the horizontal east-west component of the chromospheric field could be inferred. This revealed an unexpected amount of structure within a coronal hole. The results also confirmed predictions by the leading prominence models concerning the field direction beneath prominences. Harvey continued to develop methods to suppress CCD etalon fringes in high precision monochromatic images.

Future Research Plans
During FY 2011, J. Harvey will continue to concentrate on development of SOLIS and GONG. In particular, investigation of a more robust modulator for the SOLIS/VSM, completion of the SOLIS/FDP and final commissioning of an Hα 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.

Service
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. He participates in planning for a new solar satellite and he accepted an appointment to the Solar and Heliospheric Physics Panel of the current Solar and Space Physics Decadal Survey. Harvey presented invited lectures in Switzerland and Spain during FY 2010.

Frank Hill, Senior Scientist

Areas of Interest

Helioseismology, Asteroseismology, Fluid Dynamics of the Solar Convection Zone, 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 equator-ward 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. The latest data from this analysis suggests that Cycle 25, which should start around 2019, will either be delayed or very weak.

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 working with K. Jain and S. Tripathy on the change of frequencies during the recent deep minimum and the rise of cycle 24. They have found that the time of minimum frequencies depends on the degree of the oscillations, suggesting that the solar cycle timing is depth-dependent.

Hill has been working with the SDO HMI team to develop their ring-diagram analysis pipeline to routinely map the flows in the outer solar convection zone. Hill and his team have also started continual processing of the HMI solar far-side images, which will be distributed through NSO. They have also been developing helioseismology using the SDO Atmospheric Imaging Assembly (AIA) data, which will provide a multi-wavelength capability when combined with HMI and GONG observations.

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.

Service

Hill is the GONG program director and will take on the role as Associate Director of the NSO Synoptic Program in the near future, which will combine SOLIS and GONG. Hill serves as the NSO DigitalLibrary 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 a major proposal to the NSF Major Research Instrumentation (MRI) opportunity for a node of the Stellar Observations Network Group (SONG) project. He organized a Vector Magnetic Field Comparison Group, which held its second meeting in Palo Alto in October. Hill wrote two white papers and participated in six others for the 2010 Decadal Survey of Solar and Space Physics, and is serving on the Platforms Working Group for the survey. He is the chair of NASA's Joint Solar-C Science Assessment Team, and reviewed 10 proposals for the NSF and NASA, as well as five papers for *ApJ*, *Solar Physics*, etc. He served on the scientific organizing committee for three international scientific meetings, and has been appointed to the European HELAS Board.

Rachel Howe, Associate Scientist

Areas of Interest

Helioseismology, the Solar Activity Cycle, Peak Fitting

Recent Research Results

Howe's 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. Howe was an invited attendee and presenter at an international HELAS workshop in Birmingham, England on the subject of "The Acoustic Solar Cycle." Howe published a short paper entitled "A Note on the Torsional Oscillation at Solar Minimum," which was the subject of a press release at the 2009 AAS/SPD meeting and attracted some press and blog attention. She is a co-investigator on the Helioseismic and Magnetic Imager (HMI) instrument launched aboard the Solar Dynamics Observatory and as such has been involved in regular telecons with the Stanford team. Howe is also involved in the analysis of preliminary stellar oscillations data from the Kepler spacecraft.

Service

In addition to the research activities described above, Howe shares with R. Komm the (informal) responsibility for checking the results of both the GONG PEAKFIND analysis and the 'ring diagram' pipeline. Howe also maintains the layout for the GONG resources CD, which is widely distributed.

*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. A 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, she 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.

Service

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

*Nina V. Karachik, Research Associate

Areas of Interest

Solar Corona, X-ray and EUV Coronal Bright Points, Coronal Holes and Fast Solar Wind Streams, Filaments.

Recent Research Results

The results of exploring formation of coronal holes on the ashes of decaying active regions are the following: we have found that as each active region dissipates, one polarity flux that is more compact (and also has more vertical orientation) tends to persist longer than the other polarity. This asymmetry in dissipation rates may lead to a flux imbalance and formation of isolated coronal hole. Number of active regions associated with coronal holes does not show cycle variations. Polarity of coronal holes shows stronger correlation with polarity of background field than polarity of more compact part of active region. These results were presented at the 216th AAS meeting in Miami in May 2010, and published in *The Astrophysical Journal*. The most recent research is on fast solar wind and its association with coronal bright points inside non-polar coronal holes. The result of that research is submitted to *The Astrophysical Journal* and will be presented as a poster on AGU Fall meeting in San-Francisco in December 2010. The results suggest that the reconnection processes occurring in coronal bright points might not serve as the main mechanism of fast solar wind acceleration. That conclusion based on lack of strong correlation between solar wind speed and coronal bright points inside coronal holes which served as source regions of fast solar wind. The strongest correlation was found for solar wind speed and coronal holes' area that is in a good agreement with the results of previous studies. It was also found that the correlation varies with solar activity: it peaks for periods of moderate activity, but decrease slightly for higher or lower levels of activity. Studied spatial distribution of bright pixels corresponding to coronal bright points inside ten coronal holes indicates that the density of bright points is higher in the inner part of coronal holes.

Future Research Plans

Karachik intends to study chromospheric features like filaments, how and why they are formed, necessary and essential conditions of their appearance and evolution during extended period of time. In particular, she plans to study correlation between filaments observed on H-alpha maps and physical parameters of magnetic neutral line, their dependence on sunspot activity cycle.

Shukirjon S. Kholikov, Assistant Scientist

Areas of Interest

Helioseismology, Data Analysis Techniques, Time-Distance Methods

Recent Research Results

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

The main focus of the pipeline is 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. Meridional flow measurements were obtained by using GONG spherical harmonic (SH) time series for 1995-2009 using travel-time differences from velocity images reconstructed from SH coefficients after applying phase-velocity and low-filters. This filtering technique increases the signal-to-noise ratio and thus extends travel-time measurements to relatively high latitudes and deep into the convection zone. Obtained depth profile shows a distinct and significant change in the nature of the time differences at the bottom of the convection zone. Preliminary inversions surprisingly indicate that there are multiple meridional cells in depth. More work must be done to verify these results.

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 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 allowed to show how this artifact changes flow direction at high latitudes which can be easily misinterpreted as a second-cell structure of meridional flow.

Results of the deep meridional flow measurements using 15 years of GONG SH time series are partly submitted and final paper is on submission stage.

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 the deep meridional flow and the measurement of flow in high latitudes. Performing inversion techniques to obtained results involving collaborators is in progress.

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

Stephen L. Keil, NSO Director

Areas of Interest
Solar Activity and Variability, Astronomical Instrumentation, Solar Convection and Magnetism, Coronal Waves, Educational Outreach, the Advanced Technology Solar Telescope (ATST)

Recent Research Results
Keil worked with REU student Olivia Telford on investigating bright point motions seen in a two- hour speckle-reconstructed movie obtained with the Dunn Solar Telescope and the high-speed G-band imager. The goal was to obtain more accurate lifetimes and velocities of the G-band bright points by hand-tracking a large number of bright points. The advantage of hand-tracking over automated routines is the ability to follow motions through the bad frames and through collisions with other bright points and granules. They measure the velocity and the curl of the velocity and derived the energetics associated with the motions. Assuming the motions represent actual motions of magnetic flux tubes, they estimated the amount of energy that was available for transfer to higher atmospheric layers through the generation of waves along the

tubes. Results of this project will be presented as a poster paper by Ms. Telford at the January 2011 AAS meeting in Seattle. Keil also continued to compare disk-integrated Ca K-line observations obtained from the Evans Solar facility with those of SOLIS in order to cross calibrate. Once the cross calibration is completed, the Evans measurements will cease.

Future Research Plans
Keil is leading efforts to develop the Advanced Technology Solar Telescope. In collaboration with Tom Schad (graduate student at the University of Arizona), Matt Penn, Gianna Cauzzi, Kevin Reardon and Alexandra Tritschler, he plans to study the association between acoustic waves and the CO structure of the chromosphere. Keil 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, and is a collaboration with researchers at NASA Ames. Time permitting, Keil will continue to work with Steve Tomczyk and Scott McIntosh of HAO on coronal waves.

Service
Keil is director of the National Solar Observatory and a member of the High Altitude Observatory advisory panel. He supervises both graduate and undergraduate students, conducting research programs during the summer, and works closely with NSO and NOAO educational outreach programs. He provides input to the current solar and space physics decadal survey on science objectives and the ATST project. Keil leads the ATST project, which is a community wide effort to build the next generation solar telescope.

*Rudolf W. Komm, Associate Scientist

Areas of Interest
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 a new technique for measuring solar subsurface meridional circulation and its variation with the solar cycle, several solar and instrumental effects that manifest in the meridional circulation measurements (offset of the solar rotation axis from the classic values and center-to-limb darkening shifting the effective center of the velocity pixels), 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 and *Kepler* missions, and modifications to the SDO/HMI and AIA frequency analysis are being pursued.

Service
Leibacher served as co-editor of the NSO section of the *NOAO/NSO Newsletter*, serves as a member of the NSO Scientific Personnel Committee, and organizes the weekly seminar series. He has been a mentor to several undergraduate (REU) students and two graduate students all using GONG data (and plans to again this year), has been the external examiner on four PhD theses and a member of six PhD juries recently. He 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-in-chief of the journal *Solar Physics*.

Matthew J. Penn, Associate Astronomer

Areas of Interest
Spectropolarimetry, Near-IR Instrumentation, Solar Atmosphere, Oscillations

Recent Research Results
Penn continues to work with W. Livingston on examining the changes in sunspot magnetic fields through Solar Cycle 24. 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. Most recently, Penn has studied solar oscillations using the 4 micron fundamental lines of CO; results indicate that the CO lines provide an extremely useful diagnostic of the solar atmosphere. Because the lines are formed in LTE and provide sensitive probes of the solar temperature, they can readily be used to measure the temperature-velocity phase relation of the solar oscillations in the atmosphere. This provides a critical diagnostic for the thermal relaxation rate of the gas, as well as more fundamental parameters such as the acoustic cutoff frequency and the ratio of specific heats.

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.

Service
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

Areas of Interest
Solar Magnetic Fields

Recent Research Results
G. Petrie has thirteen 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. Recently he worked on zero-point corrections for the GONG magnetograms and tested the results using potential field models. This work continues. He has studied GONG one-minute magnetogram data sets for 77 flares and has just published a paper summarizing the field and flux

changes, finding statistical correlations consistent with collapsing magnetic structure during flares. Petrie was also involved in the Whole Heliospheric Interval (WHI) observing and modeling campaign (*http://ihy2007.org/WHI/*). He developed nonlinear force-free models of the active-region fields of WHI with colleagues, and potential field models of the global corona for comparison with various observations. This paper was recently accepted for publication in a topical issue of the journal *Solar Physics*. At the moment he is working on methods for quantitatively comparing potential field models of the global coronal field with STEREO observations of coronal holes and streamers.

Service

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 3 NSO REU students during the summers of 2008, 2009 and 2010 to study and compare the magnetic field tilt angles in the photosphere and chromosphere and the influence of active regions on the global coronal field. Some of this work has appeared in the *Astrophysical Journal* and some is being prepared for publication. Petrie sat on NASA proposal review panels in 2006 and 2009 and participated in an NSF proposal merit review in 2010.

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 U.S. and international institutions on helicity of solar magnetic fields, properties and solar cycle variations of coronal bright points, evolution of coronal holes, role of CMEs in driving chromospheric Moreton waves, formation of chromospheric filaments, orientation of magnetic bipoles as indication of extended solar cycle, and implementation of SOLIS/VSM magentograms in nonlinear force-free field extrapolation.

A previously unobservable mirror asymmetry of the solar magnetic field – a key ingredient of the dynamo mechanism which is believed to drive the 11-year activity cycle – has recently been measured. This was achieved through systematic monitoring of solar active regions carried out for more than 20 years at observatories in Mees, Huairou and Mitaka. A detailed analysis of vector magnetic field data and current helicity, based on observations from Huairou Solar Observing Station in China, has shown that like sunspots helicity patterns propagate equator-wards, but unlike sunspot polarity helicity in each solar hemisphere does not change sign from cycle to cycle, thus confirming the theory. There are, however, two significant time-latitudinal domains in each cycle when the sign briefly inverts. These findings shed new light on stellar and planetary dynamos and are yet to be included in the theory.

The formation of isolated non-polar coronal holes (CHs) on the remnants of decaying active regions (ARs) at the minimum/early ascending phase of sunspot activity has been investigated. The evolution of four bipolar ARs has been followed, and several parameters of their magnetic fields including total flux, imbalance, and compactness have been measured. As regions decay, their leading and following polarities exhibit different dissipation rates: loose polarity tends to dissipate faster than compact polarity. As a consequence, one can see a gradual increase in flux imbalance inside a dissipating bipolar region, and later a formation of a CH in place of more compact magnetic flux. Out of four cases studied in detail, two CHs had formed at the following polarity of the decaying bipolar AR, and two CHs had developed in place of the leading polarity field. All four CHs contain a significant fraction of magnetic field of their corresponding AR. Using potential field extrapolation, it has been shown that the magnetic field lines of these CHs were closed on the polar CH at the North, which at the time of the events was in imbalance with the polar CH at the South. This topology suggests that the observed phenomenon may play an important role in transformation of toroidal magnetic field to poloidal field, which is a key step in transitioning from an old solar cycle to a new one. The timing of this observed transition may indicate the end of solar cycle 23 and the beginning of cycle 24.

Multi-instrument observations taken during April, 2007, a period of extremely low sunspot activity, have been used to investigate the properties of magnetic fields and their potential role in formation of the chromospheric filaments. For one studied case, it was found that some of the necessary conditions for forming a filament: a well-developed filament channel does exist, and overlying arcade is present, but apparently there is insufficient material in Hα in chromosphere to form an enduring filament. Furthermore, when plasma, observed in He II 304A, is injected into the filament channel, we do see an Hα filament appearing for a short period of time. Therefore, it was concluded that the main reason for absence of filaments in Hα is that a mechanism supplying material for a filament into the filament channel does not work as efficiently as in other periods of solar activity cycle.

Synoptic full disk longitudinal magnetograms were employed to study latitudinal distribution and orientation (tilt) of magnetic bipoles in the course of sunspot activity during cycles 21, 22, and 23. The data set includes daily observations from NSO at Kitt Peak (1975-2002) and Michelson Doppler Imager on board the Solar and Heliospheric Observatory (MDI/SOHO, 1996-2009). Bipole pairs were selected on the basis of proximity and flux balance of two neighboring flux elements of opposite polarity. Using the area of the bipoles, the bipoles were separated into small quiet-Sun bipoles (QSBs), ephemeral regions (ERs), and active regions (ARs). It was found that in their orientation, ERs and ARs follow Hale-Nicholson polarity rule. As expected, AR tilts follow Joy's law. ERs, however, show significantly larger tilts of opposite sign for a given hemisphere. QSBs are randomly oriented. Unlike ARs, ERs also show a preference in their orientation depending on the polarity of the large-scale magnetic field. These orientation properties may indicate that some ERs may form at or near the photosphere via the random encounter of opposite polarity elements, while others may originate in the convection zone at about the same location as ARs. The combined latitudinal distribution of ERs and ARs exhibits a clear presence of Spörer's butterfly diagram (equatorward drift in the course of a solar cycle). ERs extend the ARs' "wing" of the butterfly diagram to higher latitudes. This high latitude extension of ERs suggests an extended solar cycle with the first magnetic elements of the next cycle developing shortly after the maximum of the previous cycle. T he polarity orientation and tilt of ERs may suggest the presence of poloidal fields of two configurations (new cycle and old cycle) in the convection zone at the declining phase of the sunspot cycle.

Digitized images of full-disk Ca K spectroheliograms from two solar observatories were used to study the cycle variation of ephemeral regions (ERs) over the ten solar cycles 14–23. The monthly averaged unsigned latitude of ERs has been calculated, and compared with the annual sunspot number. It has been shown that the average latitude of ERs can be used as a predictor for the strength of a solar cycle. For a short-term prediction (dT ~ 1–2 years), the maximum latitude of ERs (in the current cycle) defines the amplitude of that cycle (the higher the latitude of ERs, the larger the amplitudes of the sunspot cycle). For a long-term prediction (dT ~ 1.5 solar cycles), the latitude of ERs during the declining phase of the n-th cycle determines the amplitude of the (n + 2)-th cycle (the lower the latitude of ERs, the stronger is the sunspot cycle). Using this latter dependency, the amplitude of sunspot cycle 24 has been forecasted to be at W = 92 +/13 (in units of annual sunspot number).

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. Some of these future studies will increasingly employ SOLIS data.

Service

Pevtsov is the program scientist for SOLIS. He also leads the NSO participation in digitizing NSO/Sac Peak historic data: Hα flare patrol film data (in collaboration with NJIT), CaK film data (in collaboration with A. Tlatov, Pulkovo Observatory), NSO/Sac Peak sunspot drawings (in collaboration with NOAA's National Geophysical Data Center), and early NSO/Sac Peak Summer Workshop proceedings (in collaboration with ADS). He reviewed proposals for NSF and U.K.'s Science and Technology Facility Council (STFC) and served as a reviewer for three professional publications, *Astrophysical Journal, Astronomy and Astrophysics, and Astrophysical Journal Letters.* A. Pevtsov supervises the NSO/SP technical librarian, and is a member of Time Allocation Committee for NSO/SP. He mentored one undergraduate student and a postdoctoral researcher. 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), ATST, Instrumentation

Recent Research Results

Between 2008 and 2010, Rimmele has co-authored over 30 papers in refereed astronomical journals and technical 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 has submitted an invited "Solar Adaptive Optics" review article to NASA Living Reviews. Rimmele leads the NSO and ATST solar adaptive optics (AO) and Multi-Conjugate AO programs. He works closely with the NJIT/BBSO, where he has an appointment as Research Professor and co-authored a successful ATI and MRI proposals for the development of high-order AO and MCAO systems for the 1.6 m New Solar Telescope at BBSO. In collaboration with graduate students from Kiepenheuer Institute, Freiburg and postdocs at NSO and the University of Florida, he successfully implemented an on-sky MCAO demonstrator at the Dunn Solar Telescope. Rimmele co-authored 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 Applied Optics (*ApOpt*, **49**, issue 31, p. G105,) and a number of SPIE, COSPAR and other conference proceedings. Rimmele is a Co-I for the HINODE SOT/FPP. He spent two months at the National Astronomical Observatory of Japan (NAOJ) in Tokyo as *Hinode* Guest Investigator. He gave several invited talks and lectures at NAOJ and University of Kyoto.

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.

Service

Rimmele is project scientist for the ATST and serves as Associate Director at NSO/SP. He leads the ATST Science Team, directs the effort for major ATST work packages and mentors a number of students and postdocs. He leads 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 was invited to participate in European Association for Solar Telescopes (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. He continues to serve on NSF review panels and as referee of a number of papers submitted to astrophysical and technical journals.

*William H. Sherry. Research Associate

Areas of Interest

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

Recent Research Results

W. Sherry continued the photometric monitoring of solar type members of the Pleiades with Mark Giampapa. They extended 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. Sherry also continued 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. Working with NOAO's Steve Howell, W. Sherry used speckle observations of two dozen *Kepler* extrasolar planet candidates 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".

Service

W. Sherry mentored two REU students recently—Tahlia DeMaio in 2009 and Allison Merritt in 2010. W. Sherry serves as referee on 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 star parties for a local elementary schools.

*Roberta M. Toussaint, Assistant Scientist

Areas of Interest

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.

Service
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, a participant in the Family ASTRO programs, and an NSO REU co-mentor.

*Sushanta C. Tripathy, Associate 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.

Service
S. Tripathy participated in NASA proposal peer reviews.

Alexandra Tritschler, Assistant Scientist

Areas of Interest
High-resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere; solar magnetic fields; fine-structure of sunspots, simulations of the influence of atmospheric turbulence and instrumentation on solar observations; post-focus instrumentation.

Recent Research Results
The most recent research focused on two very different topics: an extensive study of (a) spectro-polarimetric observations of umbral flashes; and (b) the influence of different modulation schemes applied by current spectropolarimeters on seeing induced crosstalk.

(a) Preliminary results of spectropolarimetric observations of umbral flashes obtained with IBIS in the CaII 854.2 nm line show as expected that the Ca II lines is very well suited to investigate chromospheric umbral oscillations and flashes. In particular, the circular polarization signal shows the typical "saw-tooth" pattern that is characteristic of shock propagation. The details of the pattern, however, are very different than what is usually observed in the He I 1083 nm line, where the red and blue lobe move together. This difference is ascribed to the more extended range of formation height of the CaII IR line. The asymmetry between the motion of the red and blue lobe is the result of velocity gradients along the line of sight over the extended height range. Furthermore, the 854.2 nm line core exhibits emission reversals, which lead to episodic apparent polarity reversals in the Stokes V signal. Results will be published in the *Astrophysical Journal*. The upgrade of IBIS with a faster acquisition system will allow for future observations to study this phenomenon with a much higher cadence than before to better resolve the temporal behavior spectrally and spatially.

(b) Tritschler and colleagues started a major effort to forward model the influence of different modulation schemes, modulation locations, and approaches to detect polarization signals (slit-based or two-dimensional) on seeing induced crosstalk. The forward model takes into account atmospheric seeing, the correction of an adaptive optics system, and all optics that is commonly shared by the instruments. This study is still underway.

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 FIRS) to determine the properties of photospheric and chromospheric layers of active regions and infer their three-dimensional dynamic and magnetic structure.

Service
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. She is also the colloquium organizer in Sunspot and was/is participating in the organization of a traditional Sunspot summer workshops and future sessions at the IAU and AAS/SPD. 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

Areas of Interest

Radiative Transfer Modeling and Structure and Dynamics of the Solar Atmosphere; Modeling and measurement of polarized light and interpreting observations.

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 Hα line. Uitenbroek is performing forward modeling calculations in multi-dimensional simulations of solar magneto-convection to study the sensitivity of the Na I D lines and the Ca II infrared triplet lines to the chromospheric magnetic field. He is computing response functions, which provide a measure of the sensitivity of a spectral feature to given parameters in an atmospheric model, to estimate the heights in the solar atmosphere to which polarization signals in chromospheric lines are sensitive.

Comparison of the spatially averaged line profiles of chromospheric lines with calculated profiles from hydrostatic models shows that these lines have a strong red asymmetry in their cores. Even when the observed profiles are compared with spatially averaged profiles calculated through hydrodynamic simulations of the solar convection, this discrepancy remains. 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 and is analyzing this data in cooperation with Alexandra Tritschler at NSO and REU intern Kaylan Burleigh.

Forward calculations of polarized light that Uitenbroek has performed in modelled magnetic flux concentrations show that the linear polarization signal in chromospheric lines is very small, likely hampering the determination of the full magnetic vector field in higher layers of the solar atmosphere. These calculations serve as a guide to the necessary precision of polarimetric accuracy that is required for such determination, which is considered essential for extrapolation of magnetic field measurement into the corona.

Uitenbroek is working with Serena Criscuoli (Astronomical Observatory in Rome) on investigating the reliability of one-dimensional stellar atmosphere modeling for the calculation of spectra and the inference of physical properties in these atmospheres. This work is done by utilizing the three-dimensional version of Uitenbroek's transfer code, calculating the emergent spatially resolved spectrum and comparing it with the spectrum of one-imensional models with similar stratification. Several theoretical arguments are found that show that one-dimensional modeling is problematic for the accurate determination of stellar atmospheric properties.

Uitenbroek is working with Alexandra Tritscher on modeling the polarized radiation emerging in photospheric spectral lines from the most recent state-of-the-art sunspot models by Rempel et al. This spectral modeling serves as a check on the realism of the models, through comparison with high-resolution observations and also shows the limits of what can be observed in these lines with current and future telescopes.

With Marianne Faurobert and Claude Aime (University of Nice, France), Uitenbroek has obtained high-resolution polarimetric observations of active network on the Sun. These measurements serve to test a new method to measure the solar magnetic field from the perspective shift the change in formation height causes in the line intensity. These findings will be tested against modeling calculations with Uitenbroek's transfer code.

Future Research Plans

In the coming year, Uitenbroek plans to continue with the development of his radiative transfer code, which is considered as one of the main available transfer codes in the field. 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.

With Serena Criscuoli, Uitenbroek has developed a novel method to accurately measure the temperature gradient in the solar atmosphere. This method will be tested with observations at the DST as well as with multi-dimensional modeling in MHD snapshots. The ultimate goal is to implement this method in a satellite mission being developed by the Laboratory for Atmospheric and Space Physics (LASP) in Boulder, and to use it to refine modeling of spatially resolved solar irradiance.

Service

Uitenbroek is the program scientist for the Dunn Solar Telescope at Sac Peak. In addition, he serves as chair of the Telescope Allocation Committee. He has an advisory role in the development of the Visible-light Broadband Imager (VBI) instrument for the ATST, and is a member of the committee that formulates high-level policies for ATST operations and the ATST Science Working Group. About fifteen different researchers from 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 NSO Co-I on the PAARE proposal to NSF in cooperation with New Mexico State University in Las Cruces. He is Co-I on the IRIS SMEX proposal by Lockheed that was accepted by NASA for launch in Dec. 2012, and is Co-I on the SUMI suborbital flight run by Marshall Space Flight Center. Uitenbroek is serving on the PhD thesis committee of Sarah Jaeggli (University of Hawai‘i). He is also member of the planning working group for the next Japanese solar satellite Solar C. Uitenbroek is co-author on several white papers that have been submitted to the decadal survey for heliophysics. He regularly serves as referee for papers and in review panels for proposals. He is one of the non-European based members of the Opticon TAC that allocates time on European solar telescopes.

Friedrich Wöger, Assistant Scientist

Areas of Interest
Visible Broadband Imager (VBI), 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 Dunn Solar Telescope 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.

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 Visible Broadband Imager. Wöger is the principle investigator of the VBI, and as such has recently mostly been involved in setting the scientific and operational requirements of this prioritized instrument for the ATST.

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 and is interested in investigating advanced image reconstruction techniques based upon speckle interferometric algorithms.

Service
Wöger is the scientist responsible for developing the system requirements of the VBI. He is 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
AIA	Atmospheric Imaging Assembly (SDO)
AISES	American Indian Science and Engineering Society
aO	Active Optics
AO	Adaptive Optics
ARRA	American Recovery and Reinvestment Act
ATI	Advanced Technology Instrumentation (NSF)
ATM	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
CAMAC	Computer Automated Measurement and Control
CD-ROM	Compact Disk – Read Only Memory
CDUA	Conservation District Use Application
CDUP	Conservation District Use Permit (Hawai‘i Dept. of Land & National Resources)
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)

DSP	Digital Signal Processor
DST	Dunn Solar Telescope
EAST	European Association for Solar Telescopes
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)
FAA	Federal Aviation Administration
FDP	Full-Disk Patrol (SOLIS)
FDR	Final Design Review
FEIS	Final Environmental Impact Statement
FLC	Ferroelectric Liquid Crystal
FOV	Field of View
fps	Frames per second
FTEs	Full Time Equivalents
FTS	Fourier Transform Spectrometer
FY	Fiscal Year
GB	Giga Bytes
GNAT	Global Network of Astronomical Telescopes (Tucson)
GONG	Global Oscillation Network Group
GPU	Graphical Processing Unit
GSFC	Goddard Space Flight Center (NASA)
HAO	High Altitude Observatory
HAO/ASP	High Altitude Observatory Advanced Stokes Polarimeter
HO	Haleakalā High Altitude Observatory
HOAO	High Order Adaptive Optics
HR	Human Resources
IBIS	Interferometric BIdimensional Spectrometer (Arcetri Observatory)
ICC	Integrated Circuit Card
ICD	Interface Control Document
ICS	Instrument Control System
IDL	Interactive Data Language
IfA	Institute for Astronomy (University of Hawai`i)
IFU	Integrated Field Unit (McMath-Pierce Solar Telescope Facility)
IHY	International Heliophysical Year
IR	Infrared
IRIS	Interface Region Imaging Spectrograph (*Hinode*)
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

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	Living With a Star
McMP	McMath-Pierce
MCAO	Multi-Conjugate Adaptive Optics
MCC	Maui Community College
MEDB	Maui Economic Development Board
M-E	Milne-Eddington
MHD	Magnetohydrodynamic
MKIR	Mauna Kea Infrared
MREFC	Major Research Equipment Facilities Construction (NSF)
MRI	Major Research Instrumentation (NSF)
NAC	NSO Array Camera
NAI	NASA Astrobiology Institute
NAS	National Academy of Sciences
NASA	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
NOAO	National Optical Astronomy Observatory
NOI	Notice of Intent
NRC	National Research Council
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	Office of Management and Budget
OP	Operations Plan
O-SPAN	Optical Solar Patrol Network (formerly ISOON)

PAARE	Partnerships in Astronomy & Astrophysics Research & Education (NSF)
PAEO	Public Affairs and Educational Outreach (NOAO)
PCA	Principal Component Analysis
PDR	Preliminary Design Review
PI	Principal Investigator
PMCS	Project Management Control System
PSPT	Precision Solar Photometric Telescope
QA/QC	Quality Assurance/Quality Control
QSA	Quasi-Static Alignment
RASL	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
SDEIS	Supplemental Draft Environmental Impact Statement
SDO	Solar Dynamics Observatory
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
SSB	Source Selection Board (ATST)
SSP	Source Selection Plan (ATST)
SST	Swedish Solar Telescope
SSWG	Site Survey Working Group (ATST)
SWG	Science Working Group (ATST)
STEM	Science, Technology, Engineering and Mathematics
STEP	Summer Teacher Enrichment Program

TAC	Telescope Time Allocation Committee
TB	Tera Bytes
TCS	Telescope Control System
TLRBSE	Teacher Leaders in Research Based Science Education
TMA	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
USFWS	U.S. Fish and Wildlife Service
VCC	Virtual Camera Control (ATST)
VCCS	Virtual Camera Control System (Dunn Solar Telescope)
VMCG	Vector Magnetogram Comparison Group
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