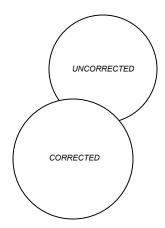
LONG RANGE PLAN FY 2003-2007

ORIGINS OF SOLAR MAGNETIC VARIABILITY







On the cover: These images of a sunspot, taken with the new NSO/NJIT high-order AO system at the Dunn Solar Telescope, demonstrate that even in mediocre seeing conditions, diffraction-limited imaging can be provided by the new high-order AO system. Time sequences of corrected and uncorrected images show that the new AO system provides fairly consistent high-resolution imaging even as the seeing varies substantially, as is typical for daytime conditions. See NOAO/NSO Newsletter No. 74 (June 2003, page 30; http://www.nso.edu/press/74news.pdf) for full images and information. See also http://www.nso.edu/nsosp/ao/ for details about the Solar Adaptive Optics Program.

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MISSION

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

NSO accomplishes this mission by:

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

RESEARCH OBJECTIVES

The broad research goals of NSO are to:

- Understand the mechanisms generating solar cycles 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 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 Mechanisms of coronal heating, flares, and coronal mass ejections which lead to effects on space weather and the terrestrial atmosphere.
- **Explore the unknown** 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 utilizes a multi-faceted approach to solar astrophysics through the establishment of innovative facilities with state-of-the-art instrumentation combined with forefront research by its scientific staff. This approach enables members of the scientific community to pursue their individual and collective goals in solar physics through the merit-based use of advanced facilities (and universally available data archives), as well as through collaboration with the NSO staff. In this way, meaningful progress toward a full understanding of the dominant object of the solar system, the Sun, is achieved while simultaneously affirming and enhancing US leadership in solar physics. The NSO program described in this Long Range Plan will continue to invigorate US solar physics through innovative staff research and instrument development combined with broad community involvement. In so doing, the NSO plan maintains the US at the leading edge of worldwide solar physics.

The program implements the recommendations of the National Research Council's recent decadal report entitled "Astronomy and Astrophysics in the New Millennium (2001)" (Decadal Survey):

> "The survey recommends that effective national organizations are essential to coordinate and insure the success and efficiency of US ground-based optical and infrared facilities." It goes on to state that "[the NSO] currently fulfills the committees' recommended role . . . for the solar physics community."

As solar physics also shares essential intellectual and programmatic links to solar-terrestrial physics, it plays a key role in the recently released NRC Study entitled "The Sun to the Earth - and Beyond: A Decadal Research Strategy in Solar and Space Physics (2002)."

Through the development of revolutionary observational capabilities, such as the Advanced Technology Solar Telescope (ATST), the NSO program will advance our understanding of the physics of solar magnetic variability and the resulting variations in the solar outputs. The NSO plan addresses the origins of solar variations that impact Earth and the near-space environments in which we live, thus having broad societal impacts from space weather hazards to climate, and from biodiversity to life near other stars. NSO recognizes the many exciting educational opportunities that the study of the Sun uniquely offers extending across a broad range of intellectual inquiry. Accordingly, NSO will continue to expand and improve its already effective educational outreach program to reach an even wider audience, from K-12 to the scientific community, with the excitement of the new results.

The foundations of NSO's long range plans are established in the current program by reinvestment of available NSO resources, through community-wide initiatives to generate new investment, and through the NSO commitment to excellence in research, innovation and service on the part of its staff.

The successful implementation of the NSO initiatives in solar astrophysics relies crucially on the scientific leadership of the NSO staff. The foundations of this leadership role are scientific credibility and respect as attained through significant achievements in staff research combined with a history of successful instrument development. The outstanding record of achievement of the NSO in this regard is summarized herein. NSO is committed to attracting and maintaining the best possible scientific staff, including the active recruitment of women and minorities, as a prerequisite for achieving innovation in instrumentation and excellence in research. In addition, the NSO initiatives are widely acknowledged as proper national center roles that serve critical scientific and technological needs, and that do not have equivalent counterparts in the community.

NSO's long range plan recognizes that progress in understanding the Sun requires that it be treated as a global system, in which many critical processes occur on all scales, from the very small (<100 km) to scales that encompass the whole Sun, and that understanding solar magnetic fields is the key to unraveling the Sun's mysteries. As stated in the Decadal Survey:

> "The first scientific goal for advancing the current understanding of solar magnetism is to measure the structure and dynamics of the magnetic field at the solar surface down to its fundamental length scale."

Development and testing of meaningful physical models require the ability to observe and couple all these scales. The suite of instruments that NSO will operate addresses scales from below a tenth of an arcsecond to those of a solar active region (ATST), from single active regions to the whole visible hemisphere (SOLIS), and from the surface to the core (GONG). The continuous operation of these NSO facilities provides the synergistic data needed to connect observations with space-based facilities. In particular, satellite observatories measure the continuous evolution of solar fields with moderate resolution, high-energy coronal features and activity phenomena, and the propagation of these events into space. These phenomena have their ultimate origins in the solar photosphere and interior, accessible to observations with the ground-based facilities of the NSO.

NSO Plan

Key components of the NSO Long Range Plan are:

- developing a 4-meter Advanced Technology Solar Telescope on behalf of, and in collaboration with, the solar community;
- expanding the NSO current solar adaptive optics (AO) program to achieve diffraction-limited imaging at solar telescopes at NSO and at other institutions, and to develop the AO technology needed for the ATST;
- operating the current flagship facilities with AO until the ATST is on line;
- operating a suite of instruments comprising the Synoptic Optical Long-term Investigation of the Sun (SOLIS);
- operating the Global Oscillation Network Group (GONG) telescopes which were recently upgraded from 256×256 to 1024×1024 pixels (GONG++);
- an orderly transition to a new NSO structure, which can efficiently operate these instruments and continue to advance the frontiers of solar physics.

The Advanced Technology Solar Telescope (ATST)

The ATST will incorporate the current capabilities of the Dunn Solar Telescope (DST) and the McMath-Pierce Solar Telescope while representing an unprecedented extension of the capabilities of each in resolution—spatial, temporal, and spectral. Both as a necessary prelude to the ATST and as indispensable facilities for current research in solar physics, NSO operation of the McMath-Pierce and the Dunn Solar telescopes, respectively, will continue until first light at the ATST. The NSO program will only implement those upgrades in the forms of instrumentation and telescope control systems that serve as enabling technologies for the ATST. In this way, the NSO maintains a strong focus on ATST development while continuing to provide competitive capabilities for the staff and community to pursue frontier research in solar physics.

NSO Facilities and Instrumentation

The history of advances in observational astrophysics is a history of new telescopes and instrumentation. With each new instrument is a new view of the Universe, leading to new realms of discovery. The discipline of solar physics is no different in this regard. The NSO therefore pursues the development of innovative focal-plane instrumentation and image correction techniques at existing NSO facilities, which, in turn, is leading to new avenues of science. NSO has pioneered solar adaptive optics and high-resolution, groundbased solar physics as a necessary prelude to the ATST. With the advent of adaptive optics, the Dunn Solar Telescope has been "reborn" into a new role as a diffraction-limited telescope that is now obtaining state-ofthe-art observations of magnetic elements at the 0.15-arcsecond level. NSO has also pioneered the application of infrared (IR) technologies in solar physics. The McMath-Pierce Solar Telescope is the premier facility for infrared studies of the Sun, for high-resolution solar and laboratory spectroscopy from the UV to the thermal IR, and for extremely precise polarimetric measurements. At the McMath-Pierce telescope, imaging of the coolest structures in the solar atmosphere along with highly sensitive magnetic field measurements from 1-12 microns are routinely performed. Data from NSO synoptic programs, and GONG in particular, have driven significant progress in understanding solar structure, variability and magnetism. GONG collaboration with NASA's SoHO/SOI experiment has been especially effective. The new SOLIS facility on Kitt Peak, which will commence operations in 2003, will provide high-precision, daily observations of the Sun during its 25-year operational lifetime. The programs are widely used and highly leveraged, with operational support contributed by the Air Force, NASA, and other groups in addition to NSF. These partnerships have greatly strengthened US solar physics and enabled the partnering organizations to extend their programs well beyond their own means.

NSO and the Community

We encourage broad community involvement in our programs by developing partnerships with universities, other government agencies, industry and foreign institutions. Recent examples include an alliance of 22 institutions to develop a successful proposal for the ATST. Other examples include a partnership with the New Jersey Institute of Technology (NJIT)/Big Bear Solar Observatory (BBSO), the Air Force Research Laboratory (AFRL) and the Kiepenheuer Institute (KIS) in Freiburg to develop high-order solar adaptive optics. We are also discussing a second SOLIS site to be developed and operated by the Institute d'Astrofisica des Canarias (IAC) on Tenerife and perhaps a third in Australia or China. These potential sites, together with the initial SOLIS site on Kitt Peak, would comprise the SOLIS network. We will continue working closely with the Air Force and NASA to provide critical synoptic observations that, in addition to producing their own noteworthy science, also support space and other ground-based observations and real-time requirements. Other major cooperative programs include the Advanced Stokes Polarimeter and Solar Magnetism Initiative (HAO), synoptic observing programs (NASA and USAF), SOLAR-C (University of Hawaii), rebuilding the [Improved] Solar Optical Observing Network (ISOON) for the USAF, and the support NSO provides other current and planned space missions.

NSO in the Decadal Survey

The Decadal Survey committee's review of national astronomy organizations led to the following assessment:

"NSO has developed world-leading research capabilities that solidly support both the US and international community of solar astronomers."

To continue this role, NSO is committed to the development of the ATST and the operation of SOLIS and GONG as cornerstones of the US ground-based program in solar physics. NSO is committed to its cooperative work with other specific solar programs and agencies. The NASA Living with a Star (LWS) initiative will provide a particularly important synergism. This was recognized by the Decadal Survey with the high priorities received by the ATST and NASA's proposed Solar Dynamics Observatory (SDO). The survey states:

Together, A[T]ST and SDO will provide a comprehensive view of the dynamics of the solar magnetic field and lead to a much deeper understanding of cosmic magnetism. In addition, these projects will revolutionize our understanding of space weather and global change, which are influenced by the Sun because Earth and the space surrounding it are bathed by the Sun's outer atmosphere."

The NSO staff is working to address many other recommendations of the Decadal Survey, including an expansion of the SOLIS instruments to additional international sites, the development of a comprehensive and powerful data handling system for solar data, and closer cooperation with universities and other solar observatories.

Education and Public Outreach

Because of its accessibility to the public and to students of all grades, the Sun provides an ideal context for conveying many of the concepts in astronomy to a broad audience. NSO's outreach program has been an extremely effective tool for sharing the excitement of solar physics with the general public and recruiting the current generation of solar astronomers. NSO is committed to increasing its role in outreach programs at all levels. Current NSO programs include participation in Project ASTRO, the Southwest Consortium of Observatories for Public Education (SCOPE), the NSF Research Experiences for Undergraduates (REU), Research Experiences for Teachers (RET), and Research Based Science Education (RBSE) programs, as well as local challenge programs, science fairs, and career days. NSO also operates a Visitor Center with many hands-on exhibits, and maintains a WWW site with a solar tutorial. Plans over the next few years include adding WWW-based experiments that K-12 students can perform using the NSO on-line digital library and development of classroom activities and materials. In addition, NSO has a long tradition of training graduate students and postdoctoral fellows in both solar physics and instrumentation. Many of today's practicing solar astronomers and leaders have participated in NSO student programs. We will continue and strengthen these programs as recommended in the Decadal Survey.

NSO in Transition

The NSO plan calls for an orderly transition to a new NSO structure that is optimized to exploit the forefront capabilities it is developing. NSO currently maintains two sites, one at Sacramento Peak in New Mexico and one in Tucson that operates the solar telescopes on Kitt Peak and the six GONG stations around the world. Both sites have strong scientific staff and instrument programs. Because of the complementary nature of the principal facilities and staff, the two-site operation has been a major strength of the NSO while simultaneously posing organizational and programmatic challenges. The NSO plan calls for the replacement of both the DST at Sacramento Peak and the McMath-Pierce Solar Telescope on Kitt Peak with the ATST. The advent of the ATST will lead naturally to a consolidation of the NSO program. The utilization of the ATST, along with SOLIS and GONG as the cornerstones of the NSO, will become the major focus of the intellectual activity of the NSO staff in the conduct of its scientific program.

1 INTRODUCTION

The Sun influences climate, sustains life on the Earth, and affects human endeavors in space and in the Earth's atmosphere through variations in its radiative and particle output as caused by magnetic activity. Because of its proximity, the Sun presents us with the opportunity to examine with the highest possible resolution the physical processes that occur in stars and other astrophysical environments throughout the Universe. In particular, the Sun is a unique laboratory for understanding energetic plasma-magnetic field interactions and the roles magnetic fields play in astrophysics.

1.1 Scientific Significance

The Sun appears simple to casual consideration. Upon closer inspection it exhibits many enigmatic phenomena that defy explanation. Research in solar physics is a critical part of our nation's natural science program and a discipline of proven fundamental importance to physics and astrophysics. The Sun is the only star whose interior, surface, and outer atmosphere can be resolved in detail, hence providing an important and unique base for the study of fundamental physics, astrophysics, fluid mechanics, plasma physics, and magnetohydrodynamics (MHD). The interplay of these aspects of physics creates an astounding range of phenomena occurring 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 and in the search for new planetary systems that may be the sites for life in the universe.

1.2 Broad Societal Significance

We often think of astronomy as remote from our lives here on the Earth. A number of astronomical phenomena can affect—or have the potential to affect—the physical environment of our planet. Such phenomena range from a supernova event in our Galaxy to asteroid or comet impacts that could change some facet of the Earth and its immediate space environment, perhaps catastrophically. Among these astronomical phenomena, the Sun and its magnetic field have the most important and enduring influence on the Earth.

The radiative and particle outputs of the Sun, and their variations, have a controlling influence on Earth's atmosphere, climate, and near-space environment. Our existence on Earth depends on energy from the Sun. This flow of energy fluctuates for reasons that are not well understood but are apparently closely linked to the magnetic variations of the Sun. It is prudent to understand the behavior of an object that has the dominant role in sustaining life and which also affects our growing dependence on technology.

Conditions in space near the Earth are intimately linked to solar variability. As civilization increasingly utilizes space, it is important to understand the solar origins of space weather and the constraints placed upon our ability to use the benefits of space operations.

Solar variability creates geomagnetic storms that have effects on electronics, aviation, telecommunications, electric power transmission, the oil and gas industries, and railways. With further technological development, the sensitivity of society to solar disturbances will only increase. Mitigating the risks from magnetically induced solar activity will be aided by a good understanding of the causes of the activity.

There is evidence that climate is influenced by small changes in the solar output. Global warming and cooling may be partly controlled by natural changes in the Sun's output. Although an active research area, it is not yet firmly established to what extent climate is driven by solar variations.

Major policy decisions are required in the areas of utilization of space, robustness of technological infrastructure and global climate change. Solar research is envisioned to provide a scientific basis for sound public policy decisions.

1.3 Mission and Role of the National Solar Observatory

The NSO accomplishes its primary mission of advancing our knowledge of the Sun by supporting the leading research of its staff and the solar community through their use of its telescope facilities equipped with state-of-the-art post-focus instruments for ground-based observations in the visible and infrared. This powerful combination is the foundation for a record of discoveries that has contributed profoundly to our understanding of the Sun while inspiring new and deeper questions. As a national center, the NSO enables community research through its facilities, thereby contributing significantly to the progress of the field of solar physics. The NSO scientific staff provides leadership and support roles in scientific and technological research areas within NSO and for the community. Its history of accomplishments combined with its ongoing development of new science and instrumentation define the NSO as a productive institution in the true sense of the Latin origins of the word produce (pro, meaning "to go forward," and duce, meaning "to lead").

The NSO scientific staff and its community of users are active in several major areas of solar research, with emphasis on the Sun's internal structure and dynamics, the magnetic activity cycle, and the structure and dynamics of the lower solar atmosphere. To enable an observational understanding of the physics of these solar processes, the NSO staff leads in developing new instruments, facilities and techniques for advanced, Earth-based observations of the Sun. This dual mission of research and innovation in groundbased instrumentation is often pursued with partners in the community. Ground-based observations have significantly helped in the discovery of several major solar phenomena while complementary space-based observations have revealed previously unknown solar phenomena that are inaccessible to observation with Earth-based facilities. As an example of this complementary role, recent satellite missions operating at short wavelengths (e.g., Yohkoh and TRACE) have helped us understand the sources of coronal heating, such as nanoflares. However, ground-based observations at high angular resolution are required to understand the *origin* of the energy supply in the photosphere via the interaction of turbulent gas motions and the fibril field bundles.

Ground-based solar physics research takes place at several observatories around the world and at a number of university and institute facilities in the US. NSO has been charged by the US community of solar researchers, through recommendations of the recent NRC Decadal Survey, with a continuing mandate to provide forefront optical research facilities for the use of the community. In addition, NSO collaborates with and provides expertise to other institutions wishing to improve their facilities. NSO also acquires and distributes solar observational data to the research community and the public.

The following section briefly describes the scientific themes the proposed NSO program addresses including some recent research highlights and future plans to make progress in these key research areas.

2 SCIENCE PROGRAM

User and staff programs at the NSO address the highly coupled processes of the Sun, extending from the solar interior into the interplanetary medium, from sub-arcsecond scales to the Sun as a whole. It is only with this global perspective that real progress in understanding the Sun as an astrophysical system can be achieved.

The Sun is a complicated physical system that we need to understand because of its intrinsic importance to humanity and its relevance to other areas of physics and astrophysics. This complexity requires that the Sun will be studied as a system, using a wide range of observational and modeling tools. No single telescope, numerical model, or theory will tell us all that we need to know.

National, community-wide study groups have compiled key goals for solar physics in recent years. NSF and NASA have had the NAS/NRC's Space Studies Board convene the Astronomy and Astrophysics Survey Committee each decade to determine the most important future directions for astrophysical research, and the most recent decadal survey entitled "Astronomy and Astrophysics in the New Millennium (2001)" provides important guidance for solar physics. As solar physics also shares essential intellectual and programmatic links to solar-terrestrial physics, it plays a key role in the recently released NRC Study entitled "The Sun to the Earth – and Beyond: A Decadal Research Strategy in Solar and Space Physics (2002)." The 1999 NAS/NRC report "Ground-Based Solar Research: An Assessment and Strategy for the Future" focuses uniquely on ground-based solar physics. The following sections summarize the recurring major themes and NSO's pivotal role in addressing these issues.

2.1 Interior Structure and Dynamics

The development of helioseismology during the last three decades has provided the means to probe the interior of the Sun. A fundamental issue associated with the solar interior is the need for understanding of the structure and evolution of the internal rotation profile and the magnetic fields. It is believed that the interaction between the internal highly turbulent convection and magnetic fields is responsible for the 11-year sunspot cycle.

Through GONG, NSO provides a fundamental data set to study the solar interior over extended periods of time. Combined with data from the SoHO/SOI experiment, these helioseismology experiments are revolutionizing our understanding of the Sun. Using these data, solar researchers are investigating the structure of the deep solar interior, which maintains its role as a fundamental physics laboratory (with the awarding of this year's Nobel prize), the nature of the microphysics underlying the theory of stellar structure (e.g., the equation of state, opacities, diffusion of species), the structure of the upper and lower boundaries of the solar convection zone, the nature of sub-surface rotation and flows and their evolution with the solar cycle, and the nature of the excitation of the solar p-mode oscillations.

We now know that the rotation throughout the convection zone is similar to the surface rotation, that torsional oscillations penetrate to depths of 60,000 km and migrate towards the equator, the existence of a meridional flow associated with the torsional oscillations that evolves with the solar cycle, the development of counter flow cells, and the disruption of these flows by large active regions. Working with partners, new techniques have been developed for interpreting helioseismic data including local helioseismology techniques similar to terrestrial seismology for mapping flows as functions of latitude, longitude, and depth in the convective zone.

By upgrading GONG to higher spatial resolution and operating the GONG instruments over the 22-year Hale Cycle of magnetic activity, NSO will provide a substantial contribution to the data the solar community needs to advance our understanding of solar (and stellar) structure and dynamics.

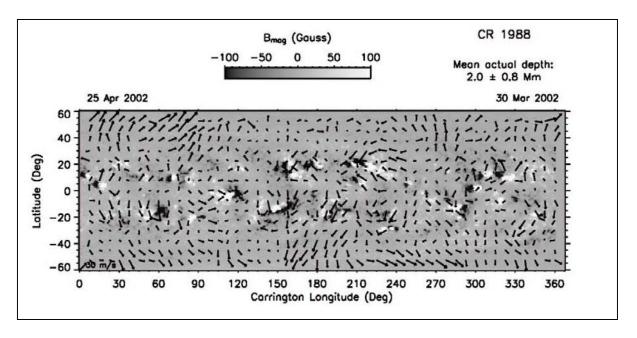


Figure 2.1. This 'solar subsurface weather map' shows flows 2 Mm below the surface over the whole Sun. These maps provide unique tools to address the origins of solar activity and are essential for understanding astrophysical fluid dynamics, such as meridional circulation and the flows around and under sunspots. The arrows indicate direction of the flow, and they correspond to horizontal velocities up to 50 m/s with a median value of 16 m/s. The background is the magnetic field.

2.2 Origin of the Solar Activity Cycle and the Dynamo

The solar cycle is thought to result from a self-excited oscillating dynamo. To understand solar activity and solar variability, we need to understand the process by which magnetic fields are generated and dissipated. There has been exciting progress in understanding how magnetic flux bundles rise through the convection zone, but that represents only part of the solar cycle process. Newer observations and modeling reveal that, besides a global (mean-field) dynamo, there also exists a turbulent dynamo. The pressing questions concern the nature of these dynamo(s) and the relationship between the changes in the interior structure, the resulting surface manifestations of magnetic activity and its modulation by the solar cycle.

The presence of a ubiquitous, weak component of magnetic field in the quiet Sun was first discovered using Kitt Peak Vacuum Telescope (KPVT) instrumentation. This weak component appears to be generated by a mechanism different from that, which produces the more common solar activity, however available data are not of sufficient quality and it is now a goal of the Synoptic Optical Long-term Investigation of the Sun (SOLIS) to address this research area.

Preliminary evidence that more magnetic flux may be generated from a small-scale turbulent dynamo than in the form of active region needs to be verified. Data acquired with the DST using the newly developed adaptive optics system and the data anticipated from the SOLIS instruments will be used to address the nature of the dynamo models.

Several discoveries by NSO users and staff bear on the problem of solar magnetic field generation. Solar magnetic flux at the two poles during minimum activity conditions does not balance and can only be balanced if low latitudes are included. There is an asymmetry in the magnetic flux distribution open to interplanetary space which was later confirmed using Ulysses *in situ* measurements. These findings suggest that the internal distribution of processes that produce the solar activity cycle is not symmetric. The monthly recurrence pattern of solar activity has been phase locked during recent solar cycles, but phase lock does not persist over many solar cycles. The phase locked signal is associated with aggregates of active regions on the Sun. Helicity of solar magnetic fields contain important information about the interaction between magnetic field and plasma in the convection zone. The hemispheric helicity rule in solar cycles 22 and 23 is independent of the solar cycle, and the interaction between magnetic field and turbulent convection in the upper part of the convection zone is a likely mechanism behind the asymmetry in helicity between the north and south.

The rotation rate at the bottom of the convection zone appears to be periodically varying in amplitude by 10% with a period of 1.3 years. This region is the tachocline, the transition zone between the solid-body rotation of the radiative envelope and the differential rotation observed at the surface and throughout the convection zone. This region is currently thought to be a location of the solar dynamo, and the discovery of the 1.3-year period provides clues to the understanding of this process. The shifts in oscillation frequencies, line widths, and amplitudes over the ascending phase of the solar cycle track several different activity measures in detail, allowing the localization of the shifts to regions on the solar surface. These regions turn out to be the activity bands. Numerical inversion techniques further indicate that the effect of the magnetic field on the oscillations is confined to a very thin layer at the surface and does not penetrate to any appreciable depth into the convection zone even though the torsional oscillation velocity pattern extends downward to substantial depths.

Planned instruments including the ATST, supported by GONG and SOLIS, will provide the data required to answer fundamental questions about the dynamo process and the solar cycle such as: How do strong fields and weak fields interact? Does the weak-field component have a large-scale structure? What is the small-scale structure of the global component? How are both generated? How do they disappear?

2.3 Transient Eruptions: Flares and Coronal Mass Ejections (CMEs)

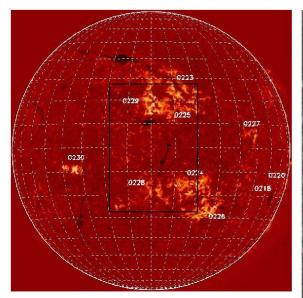
Solar flares and coronal mass ejections represent the most dramatic examples of magnetic field instabilities. Both modeling and observations are currently inadequate for a full understanding of the energy buildup and release process. In a process that is still poorly understood, the magnetic field of a streamer and its underlying filament becomes unstable and blows off into the interplanetary medium as a coronal mass ejection. Crucial questions that need to be answered concern the type of instability that leads to flares and CMEs and the processes of magnetic energy storage and release.

NSO synoptic and high-resolution measurements provide data to develop and test models of solar activity. Using regular full disk observations of the chromospheric magnetic field, which have the advantage that the field is more nearly force-free well above the photosphere and is closer to where solar activity arises, NSO scientists have revealed a component of large-scale magnetic field associated with filament channels and evidence of changes when filaments erupt during coronal mass ejections.

The orientation of the magnetic field in CMEs and magnetic clouds is one of the main factors determining the intensity of geomagnetic activity. Since these fields originate on the Sun, solar observations can be used to predict the geoeffectiveness of solar eruptions. Using NSO magnetograms and Yohkoh soft X-ray observations, 18 sigmoidal loops observed on the Sun were used to predict the orientation of the magnetic field in the leading part of interplanetary ejecta, associated with these sigmoid eruptions. Sigmoids with particular orientations were more likely to produce stronger geomagnetic storms. NSO and Air Force

scientists conducting high-resolution studies of solar active regions have revealed strong vortices in the surface flow prior to solar activity. The presence of these twisted flows may help in solar activity prediction.

NSO synoptic observing facilities currently provide some information on flares and CMEs, but crucial measurements are unavailable, such as the evolution of the vector magnetic field. SOLIS will provide these as well as a large variety of data suited to address the issue of transient activity. The DST and later the ATST will provide crucial information on the basic physical processes involved in transient eruptions.



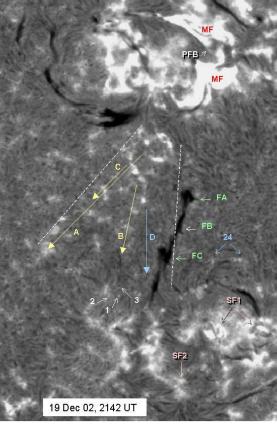


Figure 2.2. Left: Limb darkening subtracted full-disk ISOON Hα image on 19 December 2002. Right: Region of large-scale disturbance, across multiple active regions. PFB: Preflare brightening; arrows point to direction of propagating disturbances A, B, C & D, with speeds of 800 km/s, as evidenced by sequentially brightened network points, in a time sequence. These disturbances move the filaments at locations FA, FB and FC, partially erupting the filament at FC. Sympathetic flares are seen in the southern hemisphere at SF1 and SF2. SoHO/MDI magnetograms show that the brightened network points are all of same polarity. The coronal manifestations of this large-scale event include transequatorial loops, and coronal dimming, as observed by SoHO/EIT. These and similar events recorded by ISOON show that such large scale coronal eruptive events trigger near simultaneous surface activity separated by distances on the same scale as coronal structures involved in the eruption.

2.4 Origin of Solar Variability

A key discovery in astrophysics is that the Sun exhibits subtle but detectable variations in its radiative output. The irradiance variability of the Sun is indisputably related to magnetic structures that permeate the solar atmosphere. We now know that a variable solar "constant" must be taken into consideration when constructing models of global climate change. Although the causal links between the Sun's

luminosity and spectral variability and the Earth's climate are not well understood, we cannot ignore the observed correlation between measurable climatic changes and solar variations. Understanding the nature of solar variability over yearly and longer time scales, combined with models of the response of global climate to solar variability, will help understand its true impact on terrestrial climate.

NSO scientists have discovered that the strength of the helium 1083 nm line averaged over the solar disk closely tracks the variations of solar irradiance at Earth (minus the contribution from sunspots). Extrapolating the signal to zero indicates that the solar irradiance could not drop a large amount compared to its present typical value—a result important for the study of long-term Sun-climate associations. However, recent measurements show a puzzling discrepancy between various activity indicators and the actual solar irradiance. This indicates that there may be a changing component of the solar irradiance of unknown origin. The measured daily variation of solar spectral emissions in several coronal, chromospheric, and photospheric lines for the past few solar cycles have helped establish correlations between spectral variations that can be measured from the ground and the UV/EUV emissions of the Sun, which must be measured from space.

NSO in collaboration with HAO and the RISE/PSPT community has embarked on a comprehensive program of precise measurements of all the factors that contribute to an understanding of solar magnetism as the underlying cause of solar variability. Significant discoveries include the understanding of the nature of bright rings around sunspots. The KPVT (to be followed by SOLIS) provides the basic magnetic field maps that have been successfully used in modeling solar irradiance variations. The network of RISE/PSPT provides highly accurate intensity images of the Sun to identify the regions with increased or decreased solar irradiance.

2.5 Heating of the Outer Atmosphere and the Origin of Solar Wind

The fact that temperatures in the chromosphere and the corona are generally higher than temperatures in the photosphere indicates that a non-thermal process heats the upper solar atmosphere. Several mechanisms for the non-thermal heating have been studied, but combining observations and models to identify the mechanism(s) have yet to show promise. Similarly, the detailed mechanism responsible for the acceleration of the solar wind has been elusive. The questions to be answered are related to the nature of the mechanism(s) responsible for heating the chromosphere and the corona and the mechanism(s) responsible for heating and accelerating the solar wind.

Regions of open magnetic field on the Sun coincide with coronal holes and high-speed solar wind streams that can create geomagnetic storms. KPVT magnetograms are used to compute where these open regions are. NSO conducts synoptic programs of coronal hole mapping using He I 1083 nm measurements and coronal emission line measurements that have become a major source of data on coronal holes during periods when space observations are not available. Comparisons with solar wind measurements by the Ulysses spacecraft have shown a good correlation.

Using Yohkoh SXT images and NSO magnetograms, studies of the temporal variation of X-ray and magnetic flux in selected areas of quiet Sun show that the magnetic and X-ray fluxes in the quiet Sun areas do not correlate well with each other. Instead, the X-ray radiation from active regions has a very strong effect on the X-ray flux from the quiet Sun areas. The large-scale reconnection process between the large-scale magnetic field and the field of active regions may be responsible for the quiet Sun corona. Small-scale magnetic reconnective processes could account for these anomalous profiles. Time series of magnetic and velocity field data show that emerging magnetic flux and strong downflows in the chromosphere are associated with the anomalous profiles. A heuristic model that combines buoyant

magnetic fields, convective collapse, gas evacuation, shock formation, heating, and a multi-component model atmosphere can reproduce these profiles and provides information on chromospheric heating.

The McMath-Pierce telescope allows observations of the cool component of the chromosphere by studying carbon monoxide in the thermal infrared. Such combined measurements in the optical and thermal IR are necessary to diagnose the structure of the chromosphere and the resulting heating mechanisms. The ATST will have a major impact in understanding coronal structure and heating. For example, it can be used to detect, MHD waves in the photosphere by measuring temporal variations of the Stokes parameters in individual flux tubes.

2.6 Surface and Atmosphere Structure and Dynamics

The solar atmosphere is threaded with a vast array of small-scale, highly dynamic structure that has a profound effect on local dynamics, energy flow and radiative transfer, all of which indicate the presence of dynamic processes that are not understood. Specific issues to investigate include the cause of strong intermittency of magnetic fields in the photosphere, the mechanism that energizes solar global oscillations, and the three-dimensional structure of coronal magnetic fields and its relation to the corona's thermal and dynamic evolution.

Using the newly developed adaptive optics system and image reconstruction techniques, NSO and visiting scientists have obtained the highest resolution time sequences of solar magnetic, intensity, and velocity fields ever made (~0.14"). They have discovered a wealth of fine structure inside magnetic pores, intergranular lanes, sunspots and other features that are at or below the resolution of existing solar telescopes. Establishing an accurate physical model of small-scale flux is crucial for testing the results of numerical simulations and addressing flux formation and dynamics. NSO scientists have made observations of oscillatory magneto-convection, sub-arcsecond convective motions inside magnetic pores.

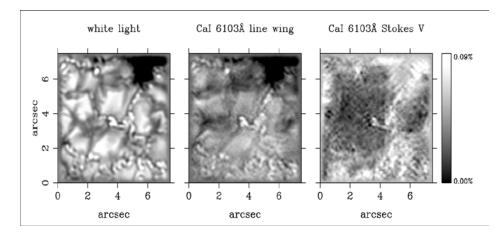
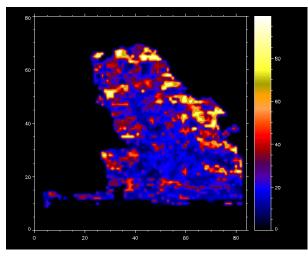
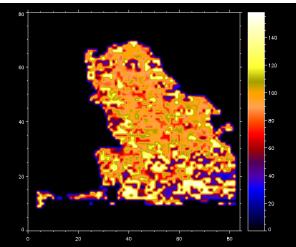


Figure 2-3. A single frame out of a time sequence showing the evolution of flux tubes at the 0.14" resolution of the Dunn Solar Telescope. The observations were made by combining adaptive optics, phase diversity, speckle imaging and speckle reconstructions techniques.

Direct measurements of coronal magnetic field strengths were obtained using a spectrograph optimized for the near IR and the NSO 16-inch coronagraph. The Evans Solar Facility's (ESF) 40-cm coronagraph was used for the experiment. Lin and colleagues designed and built a new Echelle spectrograph optimized for the Fe XIII 10747 Å and 10798 Å line pair. The first positive detection of a coronal Stokes V signal was achieved on 14 October 1999, observing in a region of the solar corona with strong (83 millionth of disk-center intensity) Fe XIIII 5303 Å green-line emission.

With the ATST, individual flux tubes will be resolved and gas motion, magnetic field, and temperature variations within and around the flux tube will be accurately measured allowing direct comparison with theory. The ATST will also provide accurate measurements of coronal magnetic fields.





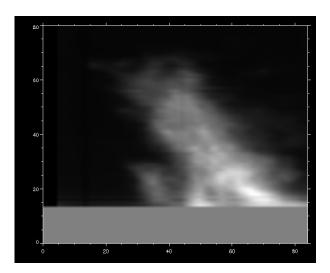


Figure 2-4. One of several prominences observed on 25 May 2002 at 16:33 UT, PA 61.8° using the Advanced Stokes Polarimeter on the Dunn Solar Telescope. This prominence was seen along almost its axis. The three maps show field strength of the He D_3 line (top), field inclination of the He D_3 line (middle), and field intensity of the He D_3 line (bottom).

2.7 The Solar-Stellar Connection

The relatively large aperture of the McMath-Pierce telescope combined with its availability for utilization at night led NSO to establish an innovative program in the study of the stellar counterparts of solar activity using high-resolution spectroscopy. The stars offer a range in physical parameter space—rotation rate, mass, convection zone depth, metallicity and so forth—that is unavailable with the Sun alone. Thus, stellar studies enable the investigation of the broad astrophysical applicability of models developed purely in a solar context.

An interesting result of this program, obtained by studying the Ca II H and K variation of solar type stars in the open cluster M67 that about one-third of the stars are more active than the Sun at the maximum in its contemporary activity cycle while 10-15% are less active than the Sun at solar minimum. Thus the Sun is likely to see much higher excursions in activity than we presently see about one-third of the time and is likely to enter Maunder minima condition (a period from 1645 to 1715 when the Sun showed very few sunspots coinciding with a period of significant cooling in Western Europe and

North America) during 10-15% of the time. Either would have profound effects on the Earth's environment.

The McMath-Pierce synoptic program of stellar spectroscopy demonstrated the potential of synoptic programs operated at facilities with nighttime capabilities. The large aperture of the ATST can be exploited for even more ambitious programs in the temporal realm of modern astrophysics.

3 TECHNICAL PROGRAM PLAN - RENEWING NSO

With the strong support and participation of the solar community, NSO has implemented a plan to develop the next generation high-resolution, infrared capable solar telescope and to continue to provide the highest quality and quantity of solar synoptic data.

The major strengths of the NSO include innovative research in conjunction with the development of new, cutting-edge instrumentation for its telescopes, often in collaboration with partner institutions. As a result, the NSO is able to efficiently operate the world's premier solar telescopes while providing the strongest possible support to visiting scientists in order to ensure high-quality observations. As we position NSO to meet the challenges of maintaining its presence as the world's premier solar observatory, these strengths need to be preserved and enhanced. This means fostering an environment that attracts the top solar astronomers and instrumentalists to develop the facilities of the future as we improve and upgrade the instruments and facilities of the present. In the case of the latter, the NSO pursues only those facility and instrument upgrades that are stepping-stones to the future.

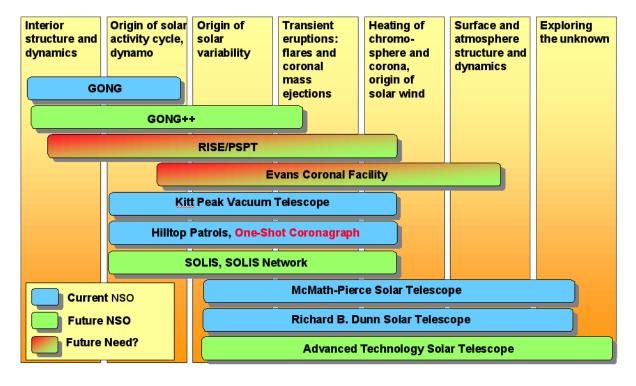


Figure 3-1. The role of current and planned facilities in addressing various areas of solar physics is illustrated. Often a combination of instruments and facilities are required to obtain comprehensive observations of physical processes on the Sun. Planned capabilities are discussed in Section 3.1 and the existing facilities in Section 3.2.

During the period covered by this proposal, NSO strategic objectives are to:

- Develop the Advanced Technology Solar Telescope.
- Complete and operate SOLIS and GONG++ and develop a synoptic network by cloning SOLIS.
- Support users at NSO's existing facilities by developing and providing state-of-the-art instrumentation such as high-order adaptive optics systems.

Figure 3-1 illustrates how current and planned assets address the scientific areas described in Section 2. The following sections describe the major initiatives of the NSO that will lead to a new era of solar physics, the current facilities that support the solar community, and the instrument development plans and upgrades that will keep the current flagship facilities at the leading edge of solar physics during the development of the ATST.

3.1 Major Initiatives

The introduction of novel, post-focus instrumentation and adaptive optics have greatly enhanced the capabilities of the solar telescopes of the NSO, thereby enabling whole new areas of scientific inquiry, especially in high resolution and infrared observations of the Sun. As a result of these developments at the NSO, it has become clear that further progress requires instrumental advances in spatial, temporal and spectral resolution combined, and that the basic limitations inherent in the current suite of NSO facilities can only be overcome by developing and building new facilities.

3.1.1 Advanced Technology Solar Telescope (ATST)

NSO is working with the solar community to develop the next generation solar telescope that will enable observations of fundamental astrophysical processes at their intrinsic scales. The major new ground-based project in solar physics is the development of the 4-m Advanced Technology Solar Telescope.

When coupled with adaptive optics, the ATST will be capable of breaking the 0.1-arcsec barrier in the visible and providing the resolution needed to analyze the fundamental structures of solar magnetic fields. Achieving high temporal and spectral resolution simultaneously with the necessary signal-to-noise (S/N) ratio requires a high photon flux, which in turn requires a large-aperture telescope (~4 m), even for the Sun. Critical diagnostics of the solar magnetic field in the low chromosphere and the corona reside in the thermal infrared, thereby adding a requirement for an all-reflective telescope and low-scattering optics.

NSO has reprogrammed a substantial part of its in-house effort to support the ATST program. During the past year this included the AO effort, building and fielding site survey instrumentation, operating the site survey and providing support to the design effort.

Additional information about the ATST and the science goals it would fulfill are available at http://atst.nso.edu/.

3.1.1.1 ATST Science Working Group and Science Requirements

The Science Working Group (Table 3.1-1), comprising both US and international members, has met several times to refine science goals and develop a Science Requirement Document (SRD). While considerable work still remains in verifying and supporting some of the specific science goals and requirements and developing specifications and derived requirements for the telescope, agreement has been reached on most of the top-level science goals.

TABLE 3.1-1. ATST Science Working Group						
Name Institution						
Thomas R. Rimmele, Chair	NSO					
Thomas Ayres	University of Colorado, CASA					
Thomas E. Berger	Lockheed Martin, Solar & Astrophysics Laboratory					
Fausto Cattaneo	University of Chicago					
G. Allen Gary	NASA Marshall Space Flight Center					
Donald E. Jennings	NASA Goddard Space Flight Center					
Philip G. Judge	High Altitude Observatory					
Stephen L. Keil	NSO					
Christoph U. Keller	NSO					
Jeffrey R. Kuhn	University of Hawaii, Institute for Astronomy					
K. D. Leka	Colorado Research Associates					
Haosheng Lin	University of Hawaii, Institute for Astronomy					
Bruce W. Lites	High Altitude Observatory					
Valentin Martinez-Pillet	Instituto de Astrofisica de Canarias, Spain					
Michael Sigwarth	Kiepenheuer Institut fuer Sonnenphysik, Germany					
Robert F. Stein	Michigan State University					
Jan Stenflo	ETH, Zurich, Switzerland					
Adriaan Van Ballegooijen	Harvard-Smithsonian Center for Astrophysics					
Haimin Wang New Jersey Institute of Technology/Big Bear Solar Ob						

Understanding and modeling the solar magnetic field is key to understanding most of the major unanswered questions in solar and stellar physics: What heats the outer atmosphere? What is the origin and cause of solar activity such as flares and mass ejections? How does the solar dynamo work and why does the Sun show cyclic variation in activity levels? Observations have established that the photospheric magnetic field is organized in small fibrils or flux tubes. These structures are mostly unresolved by current telescopes. Flux tubes are the most likely channels for storing and transporting energy into the upper atmosphere — where activity is triggered and where the solar UV and X-ray radiation emanate — which in turn affect the Earth's atmosphere. Detailed observations of these fundamental building blocks of stellar magnetic fields are crucial for our understanding not only of the activity and heating of the outer atmospheres of the Sun and late type stars, but also of other astrophysical situations such as the accretion disks of compact objects, or proto-planetary environments.

Thus, resolving and measuring the properties of the magnetic field at its fundamental scale is a primary goal for the ATST. Recent simulations of magneto-convection on the Sun indicate that a resolution of a few tens of kilometers is needed, and the polarimetric observations needed to measure the field properties require a large photon flux and accurate knowledge and control of the polarization properties of the telescope. The resolution and flux requirements drive the ATST to at least a 4-meter aperture. To achieve this aperture, the traditional vacuum or gas-filled solar telescope must give way to an open design. The other major goals of measuring the magnetic field in dark features (compared to the surrounding gas), in the upper solar atmosphere and exploiting the infrared, require an excellent control of scattered light and internal heat. Specifications for all of these elements are or will be contained in the SRD.

3.1.1.2 ATST Project Engineering and Design Progress

The ATST project team pulls from a broad range of resources. These include members of the NSO staff, individuals working from other organizations directly with this group, Co-PI teams looking at instrumentation, operations, and some design issues, and new hires specifically for the ATST. Table 3.1-2 summarizes the current staffing for ATST.

TABLE 3.1-2. ATST and Site Survey Staffing							
ATST							
Position	Name	Loading	Funding Source				
Project Director	Keil, Steve	0.5	NSO				
Education & Outreach	Dooling, Dave	1	ATST				
Project Scientist	Rimmele, Thomas	0.5	NSO				
Visible Polarimetry Scientist	Keller, Christoph	0.4	NSO				
Near IR Polarimetry Scientist	Penn, Matt	0.3	NSO				
Narrow Band Filter Scientist	Balasubramaniam, K.S.	0.1	NSO				
Thermal IR Scientist	Uitenbroek, Han	0.1	NSO				
Site Survey Scientist	Hill, Frank	0.5	NSO				
Site Survey Science Support	Radick, Richard	0.3	USAF				
Site Survey Manager	Hegwer, Steve	0.3	NSO				
Site Survey Engineer	Briggs, John	1	ATST				
Site Survey Software	Fletcher, Steve	0.3	NSO				
Project Manager	Oschmann, Jim	1	ATST				
Deputy PM	Wagner, Jeremy	1	NSO				
Admin Assistant	Purcell, Jennifer	1	ATST				
Systems Engineer	Hubbard, Rob	1	ATST				
Optical Engineer	Moretto, Gilberto	0.5	NSO				
Systems Librarian	Kneale, Ruth	1	ATST				
Mechanical Systems	Warner, Mark	1	ATST				
Thermal Systems	Dalrymple, Nathan	0.5	USAF				
Mechanical Designer	Duffek, Jerry	1	NSO				
Opto-mechanical Engineer	Price, Ron	1	ATST				
Software & Control Systems	Goodrich, Bret	1	ATST				
Software Engineer	Wampler, Steve	0.8	ATST				
16.1 F							

Initial management and systems engineering efforts have defined the design phase tasks. We have considered a range of possible subcontracting options during the construction phase and developed these options with interface requirements and project organization in mind. These include organizing an initial Interface Control Document (ICD), developing a Work Breakdown Structure (WBS) consistent with the subsystems, creating an accounting number system that matches both the WBS and ICD organization, and developing the detailed plans and schedules for the project. Lead engineers have been assigned to each of the major WBS design elements as shown in Table 3.1-3.

Funds have been budgeted to each of the major WBS elements for the design phase. Design to cost "targets" (based upon recent cost estimates) associated with each WBS element have been established. A conservative design scenario has been selected, without contingency, for the purpose of establishing these targets. It is intended to focus early design efforts towards lower cost solutions.

The current WBS is presented in Appendix A and a chart showing the interface organization (known as an "N2" chart) is available upon request.

Telescope Assembly	Mark Warner		
Telescope mount	Mark Warner		
M2 assembly	Ron Price		
M2 assembly	Ron Price		
Transfer optics	Ron Price		
Thermal systems	Nathan Dalrymple (USAF)		
Stray and scattered light control	Rob Hubbard		
Adaptive Optics	Rob Hubbard		
Instruments	Rob Hubbard		
Instrument facilities	Jeremy Wagner		
Science instruments	Jeremy Wagner		
High-level Controls and Software	Bret Goodrich		
Enclosure	Mark Warner		
Support Facilities (includes infrastructure items)	Jeff Barr (NOAO)		

Current design activities include mechanical and optical layouts for the telescope, enclosure configurations, thermal analysis and heat management, dust and scattered light analysis, and siting and construction issues. Work has centered on concepts based upon both f/2 and f/3 primaries to bracket the costs. All concepts have included considerations for a large amount of lab instrument space, but variations that impact cost have been studied. Recent progress has identified some reasonable transfer optical designs that are being developed in conjunction with the telescope and facility concepts. Input has been solicited from the instrument design teams to specify requirements for input beams.

Nathan Dalrymple of the USAF/Air Force Research Laboratory has investigated requirements and a few concepts for the prime focus heat stop, which is considered to be one of the key components of the telescope. Success with the heat stop design may indicate how fast a primary is possible; this is a cost and feasibility concern. Initial analysis suggests that the heat stop designs consistent with the f/2 primary mirror design are reasonable.



Figure 3.1-1. *The most recent concept being* considered for the ATST. The concept has an Alt-Az mount configuration, a 4-meter off-axis Gregorian optical design, and a simple-feed optics arrangement to send the beam to one of two large rotating Coudé labs to allow maximum instrument flexibility. This design includes a convenient location for a high-order deformable mirror for efficient inclusion of adaptive optics from the beginning.

It also represents a compromise of the most compact telescope mount arrangement with the largest lab space that supports efficient image de-rotation.

Several potential suppliers are participating in fabrication studies for the primary mirror for input on process, requirements, risk and cost of polishing fast, off-axis mirrors. The project is currently seeking funds and permission to purchase a mirror blank as this is the primary schedule driver. Advanced purchase of the mirror blank can compress the schedule by up to two years. Recent efforts have failed to find a solution here, so the current schedule for completion is in 2012. We will continue to look at options.

N. Dalrymple and Myung Cho (AURA New Initiatives Office) have completed initial thermal models for a candidate primary mirror. Cho has completed a first-order finite element model and has built an air temperature profile, solar loading, and a cooling concept to size the magnitude of the thermal control requirements for the primary mirror. His modeling will eventually include thermal temperature differences to the air, thermal gradients throughout the mirror blank, and the resulting distortions to the surface of the mirror. Dalrymple has developed first-order analytic models, which compare with the basic finite element model. The first order model will be useful for quick evaluation of various control strategies. Recent temperature tests conducted in cooperation with Gemini are being used to pin our models.

MOU's for conceptual instrument design and other activities have been established with most of the Co-PI teams. The following agreements are in place:

High Altitude Observatory (Visible Light Polarimeter Design; Near IR Polarimeter Contributions).

University of Hawaii (Sky Brightness Monitor and Dust Monitor; Near IR Polarimeter Design (Lead); Site Survey Operations on Haleakala 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).

University of California, San Diego (Scattered Light Trade Studies).

Lockheed Martin (Broad-band Filter).

Other potential contributions where MOU's have not been established include:

NASA Marshall SFC (Visible Tunable Filter/Polarimeter Design).

NASA Goddard SFC (Thermal IR Instrument Design).

A recent high priority activity is the initial evaluation of the construction costs for the current concepts. M. Warner has led this effort, with input from a number of sources including other recent telescope projects such as SOAR and Gemini. An outside firm also has been employed to help with estimates of construction costs at the various sites. This is part of the effort to identify potential cost issues. Discussions with the science working group have centered around the following questions:

- What is a reasonable cost target for the ATST construction phase?
- What are reasonable options to consider if the initial cost estimates are too high?
- Can we think in terms of a modular approach for the design, allowing a functional contingency now and a future upgrade potential later?
- Can savings be achieved through a smaller system that provides most of the science desired? This is a trade of items such as achievable f ratio on the primary mirror,

smaller lab space, and smaller pier with telescope closer to the ground. Each of these could lead to lower costs, but may impact some of the science.

• What science requirements can be pushed back to future upgrades without impacting most of the science?

Cost comparisons at a detailed subsystem level were made using knowledge of real costs of similar subsystems and technology. The costs, based upon details from other projects, were normalized to currentyear dollars, and then inflated (4% per year) to reflect the timing of the work throughout the 2006-2012 timeframe. This reflects the estimated costs during the construction phase. The project management and science teams are working together to prioritize the requirements and evolve the concept development to obtain the most important science drivers in a cost effective manner. Upgradeable concepts are being investigated to allow for future growth and additions to achieve more of the science goals in the future.

3.1.1.3 ATST Site Selection

The choice of a site for the ATST is a critical aspect in its design. The dominant site requirements are: minimal cloud cover, many continuous hours of sunshine, excellent average seeing and many continuous hours of excellent seeing, good infrared transparency, and frequent coronal skies. In order to perform a quality site evaluation and selection for the ATST, an ATST Site Survey Working Group (SSWG) with broad community participation was established. This committee has representatives from other nations that have expressed interest in participating in the ATST.

The SSWG helped determine the ATST siting criteria. They will verify the validity of the site testing procedures, and together with the site survey scientists will develop a report on the quality of the sites with respect to the site requirements. This report will be given to the Project Scientist who — in consultation with the ATST Science Working Group (ASWG) — will evaluate and develop an assessment of which site (or sites) best meet each of the science requirements of the ATST. Both the site survey report and Project Scientist's assessment will be presented to the ATST co-investigators and Project Director who will then select a site for the ATST construction proposal. While the ATST partnership will emphasize the best science site, this selection process will necessarily take other non-science issues into account, such as costs, feasibility of building and funding agency concerns. The ATST project will provide estimates of building costs and building issues, once the best science site(s) is (are) known. The process can include the review of siting proposals that would reduce overall costs (e.g., shared infrastructure, waived building fees, etc.) from institutions or countries that control the top science site(s). An outside panel will review the entire site selection process to verify its validity. This panel will be formed over the next few months so they can be briefed on the process and become familiar with the site survey before seeing the final site selected for the construction proposal.

Sites currently being tested include:

- Big Bear Solar Observatory, California;
- Mees Solar Observatory, Haleakala, Hawaii;
- Observatorio Rouque de Los Muchachos, La Palma, Canary Islands, Spain;
- Sacramento Peak, New Mexico;
- San Pedro Martir, Baja California, Mexico;
- Panquitch Lake, Utah.

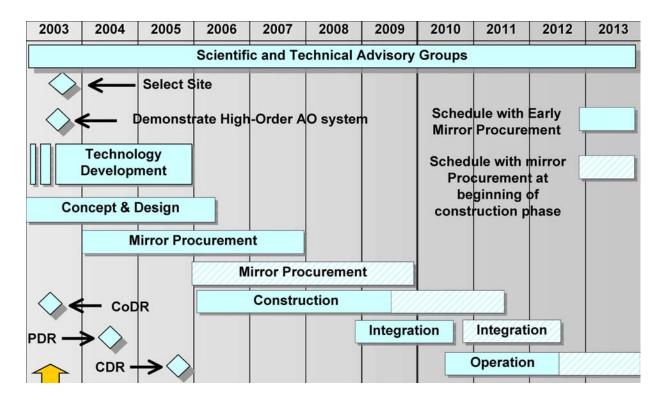


Figure 3.1-2. Summary of overall program schedule. Advancing the schedule by two years may be possible with advanced purchase of long lead items (discussed below).

3.1.1.4 Plans

During the period 2003 through 2007 covered by this long range plan, the ATST project will transition from design to construction phase. In the near-term project planning, design efforts and development of the construction proposal are the major areas of activity. Under project planning, the new WBS is being detailed to finalize the D&D program schedule. This includes major milestones such as reviews, setting up the review process and working with the partnerships to establish remaining work packages. Near-term design efforts are concentrating on thermal analysis of the telescope and enclosure, dust and scattered light, mechanical structures, and support facilities.

Project Planning

The engineer responsible for each WBS has developed detailed plans, including initial estimates of schedules for the construction phase. The systems engineer, project manager, and deputy project manager will lead the effort of integrating these details into the overall project schedule. Emphasis will be on nearterm planning, but drafts of longer-term plans through the construction phase are essential for keeping the end-project goals in mind. A schedule for the major-review milestones has been established. An overview for the D&D schedule is shown in Figure 3.1-3. Key milestones are highlighted, including the need to submit the construction phase proposal in December of 2003.

The project has established a preliminary construction phase schedule. It is shown integrated with the D&D phase in Figure 3.1-4. During the D&D phase, plans will be generated for transitioning to operations that will enable life cycle planning during the design process and help prepare the National Solar Observatory for the operational phase of ATST.

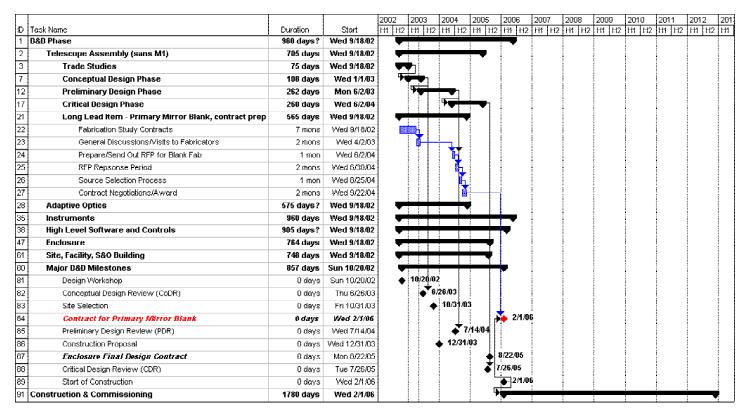


Figure 3.1-3. D &D phase schedule.

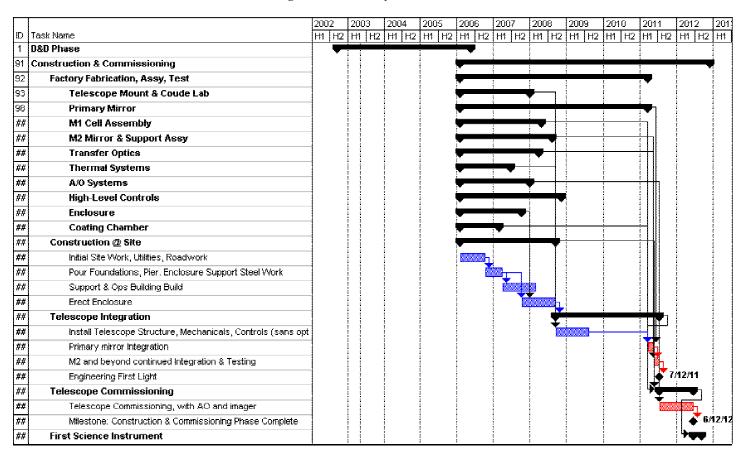


Figure 3.1-4. Construction project schedule.

If initiating purchase of the primary mirror blank in 2003 is possible, we will be able to advance the schedule for completion in 2010 instead of 2012. This effect is shown in Figure 3.1-5.

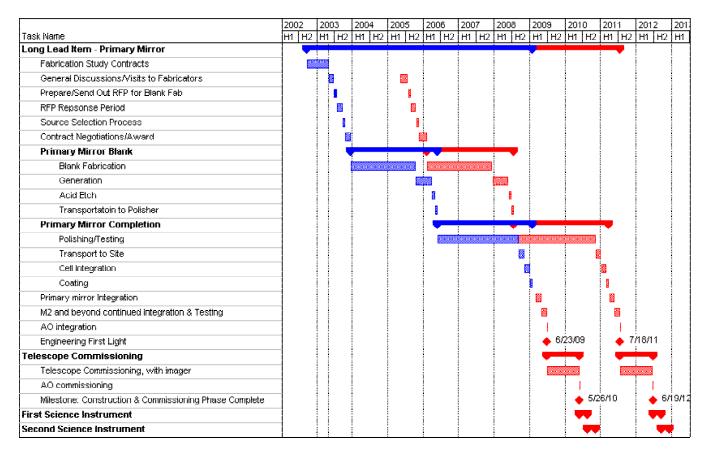


Figure 3.1-5. Long lead item schedule comparison. Purchase of the primary mirror blank could potentially result in completion of ATST two years earlier, in 2010 instead of 2012.

Conceptual Design Review (CoDR) Plans

A conceptual design review is planned for August 2003. Guidelines for conducting major system level reviews and reviews in specific areas as required were established as part of the planning process. A list of potential reviewers has been developed, from which a group of 8-10 engineers and managers will be selected to conduct the review. The ATST science community will participate through the ASWG or their designees. This process ensures adequate coverage of engineering, science, and management considerations. The intent is for three such major reviews to be held during the design and development phase, beginning with the conceptual design review.

To prepare for CoDR, a telescope design workshop was held in fall 2002. The workshop was attended by nearly 50 people, including a good fraction of those we intend to have on the engineering conceptual design review committee. Several top-level choices were made at the workshop including the selection of an off-axis design and an alt-az mount. The workshop helped to focus design efforts on the enclosure and its potential thermal properties. In addition to facilitating the identification of two of the three major trade areas for the conceptual design review, the participants highlighted the enclosure trade as the most significant area of uncertainty and encouraged the project to dedicate additional resources to it (saved from the early trades mentioned above). Several of the participants helped with developing a potential

alternative that has been labeled a 'hybrid' enclosure (Figure 3.1-1). Modeling approaches are being developed and measurements conducted on existing facilities to pin these models and plan for completion of this trade by the summer 2003.

Two other areas of concern were raised at the workshop: the schedule for producing the primary mirror for ATST and the timeline for completion of the site survey. Workshop participants encouraged the project to purchase the blank for the mirror during the D&D phase in order to save up to two years from the construction schedule. We have been pursuing options for this with the funding agencies. For site selection, Jeff Barr has visited all sites, meeting with local officials and site representatives to understand the permitting process in terms of money and time. We are keeping an open mind to the possibility of considering more than one site beyond the end of 2003, though this will entail some costs.

The following are draft priorities for the major reviews:

Conceptual Design Review (Aug. 2003)

- Major trades:
 - Telescope mount configuration (Off-axis, Alt AZ selected after workshop)
 - Optical design concept
 - Thermal control concepts
 - Enclosure concept (open, ventilated non-co-rotating, co-rating, tightly integrated, closed).
 - Instrument facility layout (Coudé, Nasmyth, Gregorian, etc.).
- First order analysis of system performance, for preferred approach(s)

Preliminary Design Review (2004)

- Preliminary design of the baseline approach established during the conceptual design phase.
- Instrument integration and operational considerations.
- Involvement of partner and manufacturing organizations in the process where possible.
 - o Intention is to have 2-3 contractors for each of three major areas of telescope design.
 - Telescope mount and associated systems.
 - Optical systems (at least for primary and secondary with active support and controls.
 - Enclosures.
 - o Partner involvement in instrumentation concepts.
- Establishment of construction costs and contingency; including draft integration, testing and commissioning plans.
- Submission of Construction Phase proposal prior to Preliminary Design Review.

Critical Design Review (2005)

- Preparing construction detailed design and specifications.
- Procurement planning.
- Integration, test and commissioning planning.
- Operational planning.

Design Activities

Design activities that will be included in the conceptual design phase are:

- Iterate beam transfer optics design concepts with partners.
- Systems modeling (thermal, optical, stray light, etc.).

Error Budgets are being established for several key observing scenarios including:

- Adaptive optics (on-disk observations).
- Seeing limited (on-disk observations).
- Coronal observations (seeing limited).
- Polarization.

Efforts will include top-down estimates to derive subsystem-engineering requirements followed by bottoms-up estimates from concepts developed to find and eliminate problem areas. This will permit to evaluate concepts against the top level engineering and science requirements.

Models will be produced in support of the major system trades including:

- Thermal control.
 - Seeing effects.
 - Alignment and mirror figure preliminary analysis.
- Stray light.
 - Surface roughness.
 - Dust and contamination.
 - Cleaning and protection strategy.
 - Baffling.

Design and analysis efforts supporting the major trades will have priority. These include telescope configuration, optical approach, enclosure concepts and instrument interface and facility requirements. The optical approach includes off-axis designs and iterations with partners on potential instrument designs such as visible and near-IR spectral polarimeters that are consistent with the telescope and facility conceptual designs.

Construction Phase

The planned schedule results in the first ATST scientific operation with its first instrument occurring in the second half of calendar year 2012. To maintain this schedule, the construction funding should begin in FY 2006. Advanced funding for the site environmental impact studies (EIS) may be required in 2004. We are trying to find a way to purchase the primary mirror blank during 2003. If successful, the project schedule may be advanced toward completion in 2010. The advanced funds represent about 2% of the projected construction costs and are being worked separately. The construction phase program will not be reviewed until 2004, but this small expenditure will help to ensure the possibility of meeting the planned schedules and the estimated costs. With the exception of the long lead items, the ATST team is working toward submitting the full construction proposal to the NSF by December 2003 for a funding start in FY 2006. During the first two years of construction, it will be crucial to begin immediately with some site work, as well as blank manufacture of the primary mirror, and to complete final fabrication designs and start construction of some of the main components such as the enclosure and telescope structure. We intend to have many of these items fully competed and negotiated by the end of 2005. This will expedite the start of the construction phase. By the end of 2007, the primary mirror blank should be nearly completed, much of the basic site work done, and major pieces near completion at the various

contractors. If the blank can be purchased in 2003, we would have the mirror nearly finished by the end of 2007. A straw man schedule is shown in Figure 3.1-4, and a comparison of the two scenarios presented in Figure 3.1-5.

Funding

In FY 2006 and 2007, adequate construction funding is needed in order to commit to many of the major subcontracts. An estimate of required funds is given in Table 3.1-4, assuming no advanced purchase of the primary mirror.

Table 3.1-4. Initial Construction Funding Required in 2006 and 2007 (Assuming no advanced purchase of the primary mirror, and EIS done in 2004. This is the baseline plan.)

ATST Construction-Phase Cost Estimate Summary (In Thousands of Dollars; Inflated 4% per year)								
	FY06	FY07	FY08	FY09	FY10	FY11	FY12	Total
Telescope Assembly	9,454	23,684	18,224	-	-	-	-	51,363
Adaptive Optics	3,397	3,533	-	-	-	-	-	6,930
Instrumentation	13,341	5,849	-	-	1	-	-	19,190
High-Level Controls	-	801	833	-		-	-	1,635
Enclosure	11,687	-	-	-	-	-	-	11,687
Support Facilities	7,700	-	3,188	949	-	-	-	12,636
Operations Facility	-	3,510	-	-	-	-	-	3,510
Project Costs	8,020	4,465	5,861	5,700	5,928	6,165	3,767	39,905
Integration, Test, Commissioning	-	-	-	-	ı	9,443	4,722	14,165
Total 53,599 41,843 28,106 6,649 5,928 15,608 8,488 161							161,021	

Table 3.1-5 shows the required funds if the mirror blank is purchased in 2003.

Table 3.1-5. Initial Construction Funding Required in 2006 and 2007 (Assuming advanced purchase of long lead items (Primary Mirror) and EIS done in 2004)

ATST Construction-Phase Cost Estimate Summary (In Thousands of Dollars; Inflated 4% per year)							
,	Total						
Telescope Assembly	17,272	24,585	2,626	-	-	44,483	
Adaptive Optics	3,397	3,533	-	-	-	6,930	
Instrumentation	13,341	5,849	-	-	-	19,190	
High-Level Controls	-	801	833	-	-	1,634	
Enclosure	11,687	-	-	-	-	11,687	
Support Facilities	7,700	-	3,188	949	-	11,837	
Operations Facility	-	3,510	-	-	-	3,510	
Project Costs	9,497	6,002	6,242	6,096	3,828	31,665	
Integration, Test, Commissioning	-	-	-	8,731	4,540	13,271	
Total 62,894 44,280 12,889 15,776 8,368 144,207						144,207	

\$2,000,000 is currently being requested to purchase the primary mirror blank as a long lead item in 2003/04. We expect to request another \$100,000-\$800,000 for site environmental impact statements and related permitting work for one to two sites. These dollars would be needed in 2004 and have been added to the D&D phase estimates shown in Table 3.1-6. Funding at this level would result in lower overall project costs (by \$14M) and advance the schedule to completion in 2010 instead of the current baseline of 2012.

Table 3.1-6. D&D Expenses for FY 2003 through FY 2005 (Shown with additions for a mirror blank and EIS costs)

(In Thousands of Dollars)

ATST	FY 2003	FY 2004	FY 2005
NSF/AST D&D Proposal	2,400	2,600	2,500
NSF/ATM D&D Proposal	200	200	200
ATST Advanced Mirror Purchase		2,000	
ATST Site EIS		800	
Total Funding	2,600	5,600	2,700

The percentage breakdown for the construction costs is given in Figure 3.1-6.

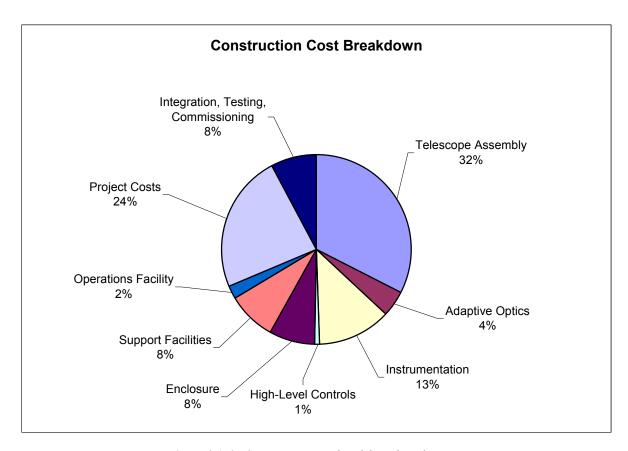
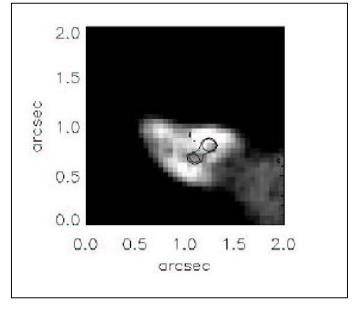


Figure 3.1-6. Construction cost breakdown by subsystem.

3.1.2 High-Order Adaptive Optics

Adaptive optics corrects for atmospheric distortion of the wavefront in order to achieve diffractionlimited imaging from ground-based telescopes. The next step in fully compensating existing telescopes and for designing the AO system needed for the ATST is the development of a high-order AO system with 80 degrees of freedom. Such a system is adequate to achieve atmospheric compensation at the Dunn Solar Telescope under median seeing conditions and diffraction-limited imaging in the near infrared under good seeing conditions at the McMath-Pierce. NSO has combined resources with the New Jersey Institute of Technology/BBSO and the Kiepenheuer Institute in Freiburg to develop high-order systems that will be installed at the DST, at BBSO and at the proposed GREGOR telescope on Tenerife in the Canary Islands.

Figure 3.1-7. The NSO adaptive optics program has resulted in a low-order AO system (correcting about 20 spatial (Zernike) modes of atmospheric turbulence), which is now in routine scientific use at the Dunn Solar Telescope. Using the low-order AO system, T. Rimmele was able to observe direct evidence for "convective collapse." This figure shows the intensity image at 90 seconds, after a dark core started to form in the center of the bright granular feature, with contours of the LOS-magnetogram overlayed. The diffraction limit of the 76-cm DST at 6302 Å is about 0.2 arcsec, and it is likely that the flux concentrations are actually significantly smaller. As the field is concentrated, darkening was observed at the location of the newly formed field concentrations while their edges become bright. This is likely the effect of radiative cooling in the center of the flux tube and the effect of radiative heating from the immediate, hot surroundings of the flux tube (hot wall effect), as predicted by theoretical models. The flux concentration occurs on a timescale of ~1 minute, which also compares well with predictions.



A major design goal for the high-order system will be to develop AO technology that is easily scalable to more degrees of freedom, so the technology will be available for the ATST. Operating experience with high-order solar AO from existing telescopes will provide important information about the efficiency achievable with solar AO systems, performance and performance limitations. This will enable us to design the most cost efficient AO system for future ground-based solar telescopes.

High-resolution observations of the Sun are essential to solving many of the outstanding problems of solar astronomy. The current high-resolution solar telescopes are in the one-meter class. These are limited because the Fried parameter (roughly speaking, the largest aperture telescope that would have diffractionlimited seeing) of a good daytime site is about 10 cm. This problem can be partially overcome by postimage processing, like speckle and phase diversity. To obtain full benefit from existing telescopes, however, one needs AO with more than 20 degrees of freedom. Going from the current low-order AO system, to a high-order, scalable system represents a major development effort.

In partnership with NJIT and KIS, NSO has started a three-year project to build three high-order AO systems for use on the 65-cm telescope at BBSO, the 76-cm DST of NSO and the planned 1.5-m German Gregory Telescope, GREGOR. These systems will upgrade leading high-resolution solar telescopes greatly improving the scientific output of each. In the meantime, the adaptation of a low-order AO system

at the NSO McMath-Pierce Solar Telescope will yield diffraction-limited imaging in the infrared. These upgraded telescopes will serve a broad solar community with diverse needs, from the individual university researcher to teams conducting campaigns.

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 not trivial. 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 to be developed in order to be able to fully exploit the scientific capabilities of AO. Having three high-order systems operating at three sites will enable us to investigate implementations of AO under the broadest of situations.

3.1.3 SOLIS and SOLIS Global Network

The Synoptic Optical Long-term Investigations of the Sun (SOLIS) project will replace many of NSO's antiquated facilities for synoptic observations of the Sun. The operational goal is to provide a continuation and improvement of a series of observations of solar variations that started in the 1970s. The SOLIS project consists of three instruments attached to an equatorial mounting, a software system to schedule and operate the facility, a data processing system, and a data archive. SOLIS will produce regular solar observations with state-of-the-art sensitivity, calibration, and accessibility. An important aspect is a seamless transition from existing facilities in a way that preserves the integrity and usability of the older data.

The three instruments are a Vector Spectromagnetograph (VSM), an Integrated Sunlight Spectrometer (ISS), and a Full Disk Patrol (FDP). The VSM is the centerpiece and will provide full-disk measurements of the vector magnetic field with high sensitivity for the first time. The ISS provides high-accuracy spectrum line profiles of the Sun observed as if it were a distant star. The FDP produces well-calibrated images of the full solar disk using several selected solar spectrum lines. Data archiving is handled by an augmentation of the existing NSO Digital Library. SOLIS will become operational on Kitt Peak in late FY 2003.

It was recommended by the recent NRC Decadal Survey that NSO should provide additional SOLIS instruments located at distant longitudes to form a SOLIS Global Network. The recommendation is under the category of "primary recommendation, ground based, small size" and says:

> "The expansion of SOLIS to a 3-station network around the globe – \$4.8 million. To gain near continuous coverage in full-disk solar vector magnetic field monitoring, as the backbone of an assessment of the solar magnetic field flux budget over the solar cycle."

A total of three instruments located at good observing sites would provide ~80% continuous observations of the Sun's varying magnetic field and photospheric and chromospheric activity. Before a proposal to fund such a network is submitted, it is necessary to demonstrate that the first SOLIS facility produces data as expected and to make collaborative arrangements with observatories located in promising locations. NSO is working hard to achieve the first of these requirements and there has been interest expressed by foreign observatories in helping to meet the second requirement. We expect to commence this project in FY 2004.

The primary goals of a SOLIS Global Network would be to study the magnetic field changes associated with flares, coronal mass ejections and the solar activity cycle. To do this effectively requires operation

for at least one Hale cycle of 22 years. The benefits of three instruments operating as an integrated system include:

- Nearly continuous data on magnetic field evolution.
- A two to three times better chance of catching rare activity.
- Improved potential for short-term activity forecasting.
- Better context data for future space missions.
- An ability to detect and correct systematic data errors.
- Robustness against a single site failure.
- Fostering of international scientific collaboration.

This project has to be flexible to accommodate the needs and involvement levels of international partners. At one extreme, it might be necessary for the US to provide most of the funding. In this case, the GONG model would be followed. If all partners contributed equal funding, a different model would be appropriate. Specifically, the partners might either build the instruments themselves or buy copies from NSO. In this case there would be federated governance of the network with joint, agreed-upon management, planning and operations. An attractive feature for potential partners is the design of the SOLIS mount. It carries the magnetograph system on one declination axis and has a second, independent declination axis capable of carrying 1500 kg of instruments provided by, and of primary interest, to the partner.

3.2 Current NSO Telescopes and Facilities

Ongoing upgrades to their focal plane instrumentation have allowed NSO telescopes to remain the most productive and useful solar telescopes in the world. Although the major NSO telescopes are three or more decades old, they still play a key role in support of US and international solar research.

3.2.1 The Flagship Facilities

3.2.1.1 Dunn Solar Telescope

The 76-cm Dunn Solar Telescope, located on Sacramento Peak at an altitude of 2804 m, remains one of the premier and bestinstrumented facilities for high-resolution solar physics. It is an evacuated tower telescope with a 1.6-m mirror stopped down to 76 cm by the entrance window. The evacuated light path eliminates internal telescope seeing. The image enhancement program over the past few years has included active control of the temperature of the entrance window to minimize image distortion and high-speed correlation trackers to remove image motion and jitter. Its new, pioneering low-order adaptive optics system provides diffraction-limited images under good seeing conditions. A high-order system that will provide diffractionlimited seeing under moderate to poor conditions is being developed. NSO has pioneered solar adaptive optics and highresolution, ground-based solar physics as a necessary prelude to the ATST.

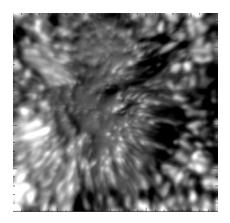


Figure 3.2-8. Velocity map of a sunspot recorded with adaptive optics at the DST. Structure close to the diffraction limit of the telescope is resolved, revealing the flows associated with the magnetic fields of the spot.

Observations with the DST have revealed the fundamental nature of convective overshoot in the solar atmosphere, led to the realization that solar oscillations are global in nature, and provided the first detection of the locations where the p-modes are excited. Using AO developed by the NSO with the DST in conjunction with the Advanced Stokes Polarimeter, developed by the High Altitude Observatory (HAO), detailed, quantitative measurements of the vector magnetic field associated with sub-arcsecond magnetic flux tubes have been accomplished. Much of our knowledge about sunspots and the evolution of solar active regions has resulted from DST observations. Detailed measurements of sunspot penumbra have revealed the mechanisms leading to the Evershed flow. High-resolution observations of surface flows have revealed twisting motions prior to activity events, which may provide a basis for solar activity prediction. Other highlights include the first measurements of prominence magnetic fields, maps of subarcsecond convective motions inside magnetic pores, oscillatory magnetoconvection, measurement of weak fields inside granules and observations of magnetic reconnection in the chromosphere.

NSO will vigorously pursue the opportunity presented by high-resolution, diffraction-limited imaging at the DST with a goal of refining ATST science objectives and requirements and ensuring the growth of the expertise needed to fully exploit ATST capabilities. With the advent of AO, the DST has seen a large increase in proposal pressure and the over subscription rate has nearly doubled. Major themes from Section 2 that this work will address include:

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

3.2.1.2 McMath-Pierce Solar Telescope

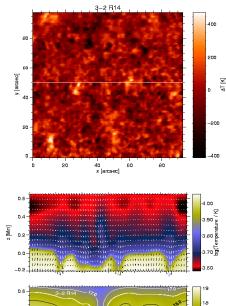
The McMath-Pierce Solar Telescope on Kitt Peak, at an altitude of 2096 m, is currently the largest unobstructed-aperture optical telescope in the world, with a diameter of 1.5 m. Thus, it is uniquely capable of panchromatic, flux-limiting studies of the Sun. In particular, it is the only solar telescope in the world on which investigations in the relatively unexplored infrared domain beyond 2.5 microns are routinely accomplished. The large light-gathering power, the extended wavelength range from the UV to the far IR, and the well-behaved polarization characteristics of the telescope are unique and have led to the first direct measurements of kilogauss magnetic fields outside of sunspots and the discovery of cold structures in the solar chromosphere. The East and West Auxiliary telescopes are among the largest solar telescopes and share the same all-reflective, unobstructed design of the main telescope. Adaptation of the low-order AO system for diffraction-limited imaging in the IR has been initiated. A large-format 1024×1024 ALADDIN array camera system is also being developed. With 16 times as many pixels, higher quantum efficiency, lower read-out noise, and better immunity from electronic interference, a 1K × 1K ALADDINbased camera will be superior to the current 256×256 camera in every respect and will enable new types of scientific observations, such as vector magnetograms of weak field concentrations and high-cadence studies of chromospheric dynamics. The last year saw several exciting developments in IR imaging spectroscopy—including the first imaging of water and other molecules in sunspots—that will be prime targets for the new camera.

Infrared polarimetery and infrared imaging developed at NSO have been combined with the McMath-Pierce Telescope to produce unparalleled, detailed magnetic maps of the photosphere. These maps reveal a ubiquitous presence of weak fields associated with turbulent convection at the solar surface that could play an important role in solar magnetic flux loss and heating of the outer solar atmosphere. Other observations with these systems have measured chromospheric magnetic fields and may provide the opportunity to directly observe coronal magnetic fields.

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

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

In brief summary, NSO has pioneered the exploration of the solar infrared spectrum. NSO's contributions include all the modern spectral atlases in the range 1.55 –18 microns; the discovery and exploitation of the most magnetically-sensitive spectral lines known to date; the discovery of pervasive spatial and temporal variability in the temperature-minimum region; and the characteri-zation of transient, small-scale magnetic fields in intergranular lanes.



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Figure 3.2-9. The Cold Chromosphere: The upper figure shows a temperature map in the chromosphere derived from McMath-Pierce observations in the 4.68micron line of CO. The lower figures show temperature and density contours in a model of convective overshoot by Nordlund and Stein. The observations confirm the prediction of cold CO clouds in the chromosphere.

3 x [Mm]

The Fourier Transform Spectrometer (FTS), located at the McMath-Pierce Solar Telescope Facility, is a unique national resource in wide demand by atmospheric physicists and chemists, as well as astronomers. The FTS is a highly stable, Michelson interferometer enclosed in a vacuum chamber. It is the only instrument of its kind in routine operation with capabilities for spectroscopy not available anywhere else in the world. With a total spectral coverage from 0.2 microns to 20 microns, the FTS simultaneously achieves 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 solar physics, laboratory spectroscopy and atmospheric sciences. Results from FTS laboratory studies have been crucial to the interpretation of data derived from the Arctic and Antarctic ozone campaigns. The unique combination of a large solar telescope with infrared capability and a high-resolution FTS instrument is ideally suited for conducting atmospheric research at this facility. More than two dozen molecules in the Earth's atmosphere, which have been identified in the McMath-Pierce FTS solar spectra, are being monitored during frequent observational runs. 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.

3.2.1.3 Global Oscillation Network Group

The Global Oscillation Network Group (GONG) is an international, community-based program, managed by NSO, to obtain data needed to support researchers in this field who are actively engaged in advancing our understanding of the internal structure and dynamics of the Sun from the surface to the deep interior, including localized structures and the solar cycle variation of the dynamics on all scales.

The GONG Program 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 sixstation, world-circling network that provides nearly continuous observations of the Sun's "five-minute oscillations." Results to date have substantially advanced our knowledge of solar internal structure from the core to the surface, and we are now beginning to measure significant structural variations and flows with the solar magnetic activity cycle, in addition to variations on shorter time scales.

The instruments continue to obtain velocity, intensity, and magnetic-field images of the Sun every minute, with approximately a 90% duty cycle, enabling continuous measurement of localized sub-surface structures and flows, as well as the use of traditional helioseismic probes closer to the visible surface. The GONG instruments are hosted by, and operate in close collaboration with, major international astronomical facilities: the New Jersey Institute of Technology's Big Bear Solar Observatory in California, the High Altitude Observatory's site on Mauna Loa in Hawaii, the IPS Radio and Space Services' Learmonth Solar Observatory in Western Australia, the Physical Research Laboratory's Udaipur Solar Observatory in India, the Instituto de Astrofisica de Canarias' Observatorio del Teide on Tenerife in the Canary Islands, and NOAO's Cerro Tololo Inter-American Observatory in Chile.

GONG will continue to refine its measurements of the time-averaged solar structure and to pursue the systematic study of variations in the structure of the solar interior with magnetic activity. After completing the camera upgrade in 2001, the sites generate 100 Gigabytes of raw data per day, and the GONG operations produce a factor of 32 increase in data flow and a concomitant increase in data storage media and processing. In order to exploit the full scientific potential of the GONG+ data, the Program has undertaken the transformation of the old workstation-based "sneaker net" data processing approach to a highly-automated, high-performance data handling system and data processing pipeline system. The full-up system should be running by the end of FY 2003. This new capability enables the investigation of global helioseismology to high spherical harmonic degree, allowing us to probe closer to the solar surface, and local helioseismology, which will allow us to probe the inhomogeneous and intermittent structure below the surface. The ring-diagram analysis pipeline has been installed and is producing new science products. Time distance and acoustical holography analyses are being implemented as well.

GONG is exploiting opportunities presented by the higher resolution cameras, continuous magnetograms, and high-performance GONG+ instruments and the GONG++ data handling system to ensure the advancement of the major topics in helioseismology, including farside imaging, as well as highresolution, high-cadence magnetograms.

3.2.2 Post-focus Instrument Development

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 first light at the ATST. This policy is consistent with the recent NAS/NRC report on ground-based solar research. Upgrades of NSO flagship facilities serve as enabling technologies for the ATST while simultaneously providing competitive capabilities for the community to continue to pursue frontier research in solar physics.

The NSO instrumentation program is focused on the development of enabling technologies that will be central to the Advanced Technology Solar Telescope and a strong program of understanding solar magnetic variability. The primary areas of instrumental initiatives at NSO are the adaptive optics program and the infrared program. Instrument development and scientific applications in these areas rely on the unique capabilities of the Dunn Solar Telescope and the McMath-Pierce Solar Telescope, respectively.

3.2.2.1 Low-Order Solar Adaptive Optics

The recent observational results (Section 2.6) achieved by using the NSO low-order adaptive optics system at the DST and at the German Vacuum Tower Telescope on Tenerife demonstrate the potential of AO for breakthrough science. The deployment of AO is rendering existing solar facilities more productive allowing users to address fundamental scientific problems, such as the structure and dynamics of magnetic flux tubes, wave propagation along magnetic elements, and generation and dissipation of small-scale magnetic fields.

The next objectives of the low-order adaptive optics program have the following goals and will set the stage for the high-order AO initiative. First, the speed of the system will be pushed beyond the current 25 Hz. The current system only corrects the image under very good seeing conditions and the faster speed will allow it to correct the images under worse seeing conditions. Post-focus instrumentation will be optimized to use the diffraction-limited imaging provided by the AO system and made available to users. Projects to upgrade the Advanced Stokes Polarimeter and narrowband filters to take advantage of the AO system are now underway and should be available to users in the time period covered by this proposal.

3.2.2.2 The Diffraction-Limited Spectro-Polarimeter

To make precise vector magnetic field observations at the diffraction limit of the Dunn Solar Telescope delivered and for observations covering the entire flux of solar active regions, a new Stokes polarimeter for the DST is currently under construction in collaboration with the High Altitude Observatory. The HAO/NSO ASP has successfully operated at the DST for almost a decade now but it is limited to 1" spatial resolution and a small field of view. The NSO adaptive optics system in combination with large format and high quantum efficiency CCD detectors allow us to redesign the ASP for high resolution, which will open new insights into flux tube physics and the formation of active regions.

The ASP upgrade is a joint effort with HAO. The basic concept is adapted from the HAO design for the spectropolarimeter that will fly on the SOLAR-B satellite. The new polarimeter will be built in three phases. The first encompasses the construction of a new spectrograph and scanner; the second includes a new camera system and new modulation, calibration and data acquisition units. The final phase will be permanently installed at the DST and will be fed by a high-order adaptive optics system that is currently under development.

The Zürich IMaging POLarimeter (ZIMPOL) developed by the Eidgenössische Technische Hochschule (ETH) in Zürich in collaboration with NSO has been used at both the DST and McMath-Pierce, along with AO, speckle, and phase diversity techniques to obtain high-spatial resolution time sequences of magnetic field evolution. The development of these scientific paths and new instrumentation will be critical to fully exploiting the even greater potential of the ATST.

3.2.2.3 Infrared Instrumentation

NSO has pioneered the exploration of the solar infrared spectrum. NSO's contributions include all the modern spectral atlases in the range 1.5–18 microns; the discovery and exploitation of the most magnetically-sensitive spectral lines known to date; the discovery of pervasive spatial and temporal

variability in the temperature-minimum region; imaging in water bands in sunspot umbrae thereby revealing the coolest temperatures yet seen in the solar atmosphere; and the characterization of transient, small-scale magnetic fields in intergranular lanes. NSO's long range plan for solar infrared studies seeks to take maximum advantage of the unique strengths of the NSO in the following areas:

- Detector technology. Infrared array detectors are at the heart of NSO's advances in solar infrared studies during the last five years. NSO will implement the next generation of solar infrared array cameras both by exploiting NOAO's leadership in the development of 1024 × 1024 InSb arrays and by collaborating with Rockwell International in the development of fast, deep-well HgCdTe arrays for high-precision polarimetry.
- High angular resolution. With the low-order AO under development for the 1.5-m McMath-Pierce Solar Telescope, its diffraction limit of 0".25 at 1565 nm can be reached under good seeing conditions, comparable to the best resolution that will be achieved from space during the next decade. The 0.76-m Richard B. Dunn Solar Telescope regularly achieves its diffraction limit of 0".5 at 1565 nm to study small-scale magnetic elements.

3.2.3 The Synoptic Facilities

3.2.3.1 Kitt Peak Vacuum Telescope

The 70-cm Kitt Peak Vacuum Telescope (KPVT), opened in 1973, is used to make daily maps of solar magnetic and Doppler fields, and intensity maps in several solar spectral lines. These synoptic data sets have proven to be very useful to understanding solar cyclic variations and for supporting space missions and other ground-based observations. The synoptic observing program at the Kitt Peak Vacuum Telescope (KPVT) — a joint effort of NSO, NASA/Goddard Space Flight Center (GSFC), and until recently NOAA/Space Environment Center (SEC) — has produced a number of research discoveries with subsequent, significant impacts. These include the discovery that magnetic flux concentrations absorb acoustic waves, which initiated the field of high-resolution local helioseismology, and the demonstration that open magnetic fields are associated with coronal holes and high-speed solar wind throughout the solar cycle, which is crucial for forecasting geomagnetic storms. Providing synoptic magnetic and chromospheric data to the solar physics community has resulted in more than 900 papers, theses, and books since 1973. The current SOLIS project will replace the KPVT capabilities when it is completed over the next year.

3.2.3.2 Evans Solar Facility

The Evans Solar Facility (ESF) provides a 40-cm coronagraph as well as a 30-cm coelostat. The Evans coronagraph is the largest in the US and most thoroughly instrumented in the world. The ESF 40-cm coronagraph is currently used extensively by both NSO staff scientists and visiting astronomers for a wide variety of research projects (e.g., coronal heating, coronal electric fields, chromospheric and coronal magnetic fields, heliospheric structure prediction, and cyclic variation of coronal structure). The ESF has provided limits of electric fields in the solar atmosphere, and discovered the rush to the poles in coronal emission lines as well as the extended solar cycle in coronal emissions. The coronagraph feeds a universal spectrograph, spectroheliograph, Littrow spectrograph, chopping coronal photometer, and a bench where PI instruments can be set-up. Recent instrumentation includes a visible and IR coronal polarimeter, which has produced tantalizing observations of coronal magnetic fields. This new instrumentation will provide core capabilities for the next generation of ground- and space-based coronal telescopes. The ESF also provides full-disk spectroheliograms in several bandpasses near the Ca II K-line and $H\alpha$. There are no plans to upgrade these capabilities as these observations will be replaced by SOLIS. The USAF provides most of the operating support for the ESF.

3.2.3.3 Hilltop Facility

The Hilltop Facility houses the white-light and Hα flare patrols, the coronal one-shot coronagraph, and a multi-band solar photometer. In addition, it has a 10-arcsec coelostat that feeds an optical bench currently used by the USAF group at Sunspot in their development of the Improved Solar Observing Optical Network (ISOON) project. The SOLIS Full Disk Patrol (FDP) is intended to replace the white-light and $H\alpha$ flare patrols, so upgrades of these systems have been frozen.

The current NSO instrumentation program is well focused on technologies that will play key roles in implementing and fully exploiting the ATST, SOLIS and GONG investments. Both the adaptive optics and infrared programs are critical to development of the ATST. Programs to improve visible and infrared detectors, including very high-speed cameras needed for adaptive optics, telescope control, and polarization measurements for vector magnetometry, will provide enabling technology for the ATST.

3.3 Digital Library and Virtual Solar Observatory (VSO)

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic data sets (daily solar images from the KPVT, 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 January 4, 2003, a total of 440,853 science data files have been distributed and 14,451 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 robotic CD-ROM jukeboxes and are searchable via a Web-based interface to a relational database. SOLIS will soon begin to generate processed data at a maximum rate of 240 GB per day, with requirements for rapid archiving and user access. Thus, a higher capacity storage system has been installed. This system, named solarch (for SOLIS or solar archive), will also hold the Digital Library contents. The solarch system currently has 6 TB of on-line RAID5 storage, and is expected to grow to 18 TB by the end of 2004.

NSO at Sacramento Peak has accumulated a significant archive of data on photographic film. These data, which represent more than 50 years of routine observations of H α prominences, coronal lines, H α flare patrol etc., are indispensable in studies of long-term evolution of solar activity. However, the practical application of data is hindered by the photographic nature of the archive. NSO plans to digitize the entire archive and make it available on-line as part of the Digital Library. We estimate that the entire project can be completed in 5 years. The proposal for digitization of NSO photographic data will be submitted to NASA and NSF at the end of 2003. Tentatively, both agencies had indicated their willingness to partially fund this project.

In order to leverage further the substantial national investment in solar physics, NSO is participating in the development of a Virtual Solar Observatory and the European Grid of Solar Observations (EGSO). The VSO, and its European counterpart the EGSO, will initially comprise a collaborative distributed solar data archive and analysis system with access through the World Wide Web. The overarching goal is to facilitate correlative solar physics studies using disparate and distributed data sets. Necessary related objectives are to improve the state of data archiving in the solar physics community; to develop systems, both technical and managerial, to adaptively include existing data sets, thereby providing a simple and easy path for the addition of new sets; and eventually to provide analysis tools to facilitate data mining and content-based data searches. None of this will be possible without community support and participation. Thus, the solar physics community is actively involved in the planning and management of the VSO. The first phase of the VSO development has been completed, and has produced a document describing the architecture of the system. An operational prototype of the VSO should be completed by

the end of 2003. NSO is leading the development of the VSO, and participating in the EGSO. The EGSO participation is currently at a low unfunded level, and a proposal has been submitted to the NSF ATM division to support NSO's role in the EGSO. For further information, see the Web pages at http://vso.nso.edu/ for the VSO, and http://www.mssl.ucl.ac.uk/grid/egso/ for the EGSO.

In the time frame covered by this long range plan (LRP), NSO should make major strides toward becoming a central component of both the VSO and EGSO. Both of these community-wide systems should be on-line by the end of this LRP period. In addition, the NSO archives should be observatorywide with components at both sites. These components should link together enhanced pipeline processing systems similar to those now available 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 http://www.nso.edu/general/docs/).

4 PUBLIC AND EDUCATIONAL OUTREACH

NSO has a comprehensive public affairs and educational outreach plan that includes undergraduate and graduate research, teacher research and research-to-classroom experiences, public programs, media information, elements of distance (Internet) learning, and K-12 education. A scientist at each site is responsible for the education and public outreach (EPO) program, receiving support from other members of the scientific and administrative staff. A recently hired public outreach officer for the ATST now coordinates outreach activities to schools, colleges and the media for both the ATST and NSO programs. NSO wants to add an EPO position to its base program and requests incremental funding (Section 5.7) to support such a position. Significant aspects of NSO's EPO Program include the NSF Funded Research Experience for Undergraduates (REU) and Research Experience for Teachers (RET), the NSO Summer Research Assistants program for graduating seniors and graduate students. As part of the ATST effort, NSO will coordinate its EPO efforts with those of its ATST partner institutions.

The ATST consortium will provide education and public outreach on several fronts that leverage and expand existing programs within the partnering groups and create unique opportunities offered by the ATST, during both its development and operation. The involvement of universities with large minority populations, the current location of NSO in regions with substantial Hispanic and Native American populations, and the geographic separation of the partnering institutions will permit us to address both ethnic and geographic diversity issues. The consortium is strongly committed to the recruitment of women and minorities in astronomy. Many of the activities described above will be developed with an eye towards supporting ATST educational goals. For example, while teaching what we have learned about the Sun through existing instruments, we can also explain the limits we now face, why ATST is needed, and what we want to learn in the coming decades.

The goals of the EPO program are:

- To increase student, teacher, and public understanding of the Sun, both as a star and as the driver of conditions on Earth.
- To foster and sustain the growth of new generations of solar physics research.
- To increase, nationally, the strength and breadth of the university community pursuing solar physics.
- To enhance the understanding and application of science and math education in our schools, colleges and the public at large.

ATST partners participate in a variety of public outreach programs through visitor centers, educational Web sites, consortia for producing and distributing outreach material, and individual efforts. Modules explaining the ATST science program and development of the telescope will be developed and distributed through these outlets. The ATST EPO officer is developing a 16-page booklet and associated posters that explain the need for and mission of the ATST. These will be made available to the news media, educators, and students. A trifold on ATST has already been developed and is being distributed.

Table 4-1 summarizes the level of EPO support embedded in its base program. In addition, NSO participates in and receives support from the NOAO's Public and Educational Outreach (PAEO) office (~\$85K). NSO makes resources available to support its EPO effort in the form of supplies and materials, computer

workstations, WWW site, housing, Visitor Center and telescope time (~\$50K). The total funds devoted to the program including the ~4 FTEs shown in Table 4-1, \$80K from NSF for the REU and RET programs, the NOAO support and non-payroll is approximately \$350K or ~4.5% of the total NSO funding. The Sac Peak Visitor Center revenues are about \$50K per year, which goes back into its operation and public exhibits.

Function	SRA REU RET	RBSE	WWW Public Outreach	WWW Sci. Data	HS/K-12 Talks	Public Tours	K-12 Tours	EPO Admin.	Total
EPO Officer (proposed New position)									1.00
EPO Coordinator (ATST Proposal)									1.00
Web Master (part time at each site)			0.60	0.20		0.20	0.10	0.10	1.20
Scientific Staff	0.50	0.10	0.10	0.20	0.10	0.10	0.10	0.10	1.30
Scientific Support Staff	0.10	0.05	0.10	0.30	0.10	0.10	0.10	0.10	0.95
Summer Students			0.20		0.10	0.20	0.20		0.70
Total	0.60	0.15	1.00	0.70	0.30	0.60	0.50	0.30	6.15

Table 4-1. Annual Education and Public Outreach (FTEs)

The following sections describe some of the NSO and ATST project EPO efforts and plans.

4.1 Higher Education (Undergraduate, Graduate, and Teacher Research and Education)

Since its formation as a national observatory in 1983, NSO has conducted an annual program that offers undergraduate and graduate students the opportunity to participate in astronomical research. In 1986, the NSO summer program became part of the NSF Research Experiences for Undergraduates (REU) program. A large fraction of active solar astronomers worldwide, plus science/engineering leaders in other disciplines, are alumni of the NSO summer programs. More than 30% of the participants in the program have been female, with this number growing to ~45% during the last five years. The program actively recruits minority students through targeted announcements to traditionally minority universities, by hosting student groups and giving them presentations on the NSO programs and their benefits, and by working with local universities with large Hispanic student populations. Since 1995, approximately 7% of participants have been from minority groups. On several occasions NSO has hosted the University of Texas-El Paso REU program for engineers, which has brought five or six Hispanic students to work at the observatory for the summer on instrument projects.

Each summer eight to twelve students—divided equally between the Tucson and Sunspot sites—participate in the program at NSO. NSO also supports several graduate students from the US and abroad under its internally funded Summer Research Assistant (SRA) program. These graduate students receive excellent training and their presence enhances the experience of the REU students. In 1998, NSO became an active participant in the Research Experience for Teachers (RET) program, which offers high school teachers a firsthand working knowledge of the applications of physics, engineering and mathematical methods for research problems and how to incorporate these methods as practical application to their classrooms. As the national center for ground-based solar astronomy, NSO has the unique advantage of offering broad exposure to the sciences of physics and astronomy. Opportunities to work at either of two locations provide a unique environment for scientific stimulation and growth. These include projects ranging from high spatial and temporal resolution studies of the interaction between the solar plasma and magnetic field, to probes of the solar interior using helioseismology, to investigations of the Sun as a star, and studies of space-weather. Many of the students and teachers also participate in instrument development programs, which provide the opportunity to learn how modern astronomical instruments are designed and built. NSO plans to enhance both its RET and REU

programs through closer coordination of research projects with ongoing space missions (such as TRACE and SoHO) and with NASA's broad outreach program, and by improving our interaction with programs at universities. In this context we have started cooperative programs with the New Jersey Institute of Technology (NJIT), for students to spend the time at NSO participating in the adaptive optics program, with the University of Rochester for a thesis student to work on instrumentation for the ATST, and for University of Arizona students to work on the ATST site survey. We plan to launch similar collaborative programs with several other universities under the ATST outreach program described below.

The science and technological aspects of ATST offer a unique opportunity to greatly increase the role of solar physics in undergraduate education. During the Design and Development (D&D) phase, we will develop educational modules designed to take advantage of the new observations and insights that will derive from ATST. We will develop a plan for integrating these into existing astronomy and physics curricula that can be implemented as the ATST becomes operational.

Several ATST graduate student positions will be established at the partnering universities. Thesis topics will comprise innovative engineering techniques, AO, scientific instrumentation, IR and optical imaging techniques, development of filter systems, observational studies exploiting AO and IR techniques at existing telescopes, and theoretical studies of fine-scale solar magnetic fields and their interactions with the turbulent solar plasma.

During the D&D phase, the ATST will provide opportunities for observational, theoretical and instrumental postdoctoral positions. Postdoctoral candidates will participate in instrumentation and analysis of site survey data, and modeling and simulation efforts related to science and engineering goals and instrument development.

NSO staff members serve as adjunct faculty at neighborhood and collaborative universities and educational institutions such as New Mexico State University in Las Cruces, the University of Arizona in Tucson, New Jersey Institute of Technology in Newark, New Mexico Institute of Technology in Socorro, and at Utah State University in Logan. In addition to organizing periodic courses in astrophysics and solar physics, NSO staff members act as adjunct supervisors to MS and PhD candidates at these institutions.

4.2 Professional Development for Science Teachers

Since the year 2000, NSO has participated in the Teacher Leaders in Research Based Science Education (TLRBSE) program developed by NOAO. This NSF-funded Teacher Enhancement program develops masterteachers to mentor novice teachers in the exemplary methods of inquiry-based research experiences. NSO provides teachers with hands-on observational opportunities to collect and analyze data on solar activity and variability. In the past, during the two-week summer institute at NOAO/Tucson, middle school teachers traveled to NSO/Sac Peak to assemble and test solar telescopes developed through the RBSE program, and to use NSO facilities. Scientists from NSO will interact with the teachers at the institute, and provide research guidance throughout the year via e-mail and the online distance-learning course being developed through TLRBSE at NOAO.

Before the RET was established, NSO participated in the New Mexico Summer Teacher Enrichment Program (STEP), which provides New Mexico teachers the opportunity to work in a research environment with materials they can use in class. Three teachers, two from Cloudcroft High School and one from Alamogordo High School have participated in projects ranging from studies of solar mass ejections using coronal data to

studies of solar rotation and variability. NSO will continue to recruit teachers from local schools (because of the demographics in New Mexico this impacts a large Hispanic and Native American student population).

In 2003 NSO exhibited at the National Science Teacher's Association national convention in order to make a wider teacher base aware of our activities and resources including the ATST. NSO will continue to present such exhibits in the forthcoming years and will seek outreach opportunities at other educational events.

4.3 SCOPE and Project ASTRO

NSO continues to participate in the Southwestern Consortium of Observatories for Public Education (SCOPE). SCOPE is a consortium of research institutions in the southwest that promote a public awareness of astronomy through access and education. Materials that describe solar astronomy and the effect of the Sun on the Earth are produced for dissemination by SCOPE. This valuable collaboration results in excellent interaction among the public and education outreach staffs of these groups and the future may include cooperative promotion, visitor center display sharing and the ability to leverage our limited funding into additional educational opportunities.

Project ASTRO is an educational outreach program initiated by the Astronomical Society of the Pacific to build relationships between astronomers and educators by encouraging interaction in the development and execution of astronomy activities in the classroom. Project ASTRO New Mexico began as an outreach to schools in the southern part of the state, and has expanded to include astronomer/teacher partnerships throughout the state. NSO was a founding member of the Alamogordo coalition and the ASTRO expansion site. NSO provides guest astronomers for the program and hosts an annual workshop for astronomers and educators.

4.4 K-12 and Other Public and Educational Outreach Programs

NSO staff members actively participate in several programs to enhance science education in grades K-12. NSO scientists are mentors to high school students in local challenge programs in Alamogordo and Cloudcroft, NM, school districts, and in Tucson, AZ, school districts, and they provide lessons and demonstrations at the Tohono O'odham (AZ) Reservation schools. NSO scientific staff volunteer as science fair judges at the Alamogordo and Tularosa Elementary Schools and participate in school educational programs of the El Paso Independent School District. NSO continues to collaborate with NOAO in their public outreach programs on Kitt Peak and in Tucson. NSO staff members participate often in Career Days at Tucson-area high schools. Using material from the GONG study of solar oscillations, NSO developed a K-3 solar music educational module. NSO staff members provide public lectures for teacher intern courses, Boy Scout troops, amateur astronomers, student clubs, business groups and senior citizens in New Mexico and Arizona. They also participate in the lecture program at White Sands National Monument, and take an active part in educational outreach booths at several fairs, including the New Mexico State Fair, Astronomy Day in Albuquerque, NM, and the Robert H. Goddard Days Fair in Roswell, NM.

NSO played a major role in the "Live from the Sun" production by Passport to Knowledge, contributing to two educational video productions, teaching materials, and three WWW chat sessions with students across the US. NSO scientists regularly provide interviews and assistance with the production of segments for national and international TV documentaries and educational films about the Sun. Past examples include programs produced by PBS, the University of Arizona, and public broadcasting stations in Australia, Japan, the United Kingdom and Chile. A CD-ROM of solar images from the NSO Kitt Peak Vacuum Telescope was produced

for public distribution, highlighting and explaining changes on the Sun that occur over the 11-year solar cycle. NSO is producing an educational CD-ROM based on GONG images from the 2003 transit of Mercury.

Currently, ATST partner organizations participate in a wide range of programs to enhance science education in grades K-12. The participation occurs through formal programs and informal commitments of staff members to local education. Modules on modern solar telescopes, solar observing techniques, and properties of the Sun, using the ATST and its capabilities as an example, will be developed in workshops, bringing teachers and researchers together through several of the programs discussed earlier. These modules will then be disseminated to classrooms throughout the country through existing outreach programs in which the ATST partners participate.

For FY 2004 and beyond, the NSO is studying development of remotely operated solar observatories that would be built around the ATST site survey telescopes (12-inch Meade SCTs). Ideally, one each would be placed at the Kitt Peak and Sunspot Visitor's Centers, and a third would be a mobile unit that could travel to schools and public events. The fixed units would have half their time allocated to solar observations by educational groups (schools, scout merit badge programs, amateur astronomy groups, etc.) and the other half to visitors at the site. The emphasis in the design would be user interactivity, offering the ability to change filters and manipulate images. An interactive system would engage students (on-line) and visitors (on site) and help us teach more about solar physics. Adding a mobile component (to be tested with an 8-inch Meade now on hand) would allow us to reach elements of the public that do not have broadband Web access or who might otherwise not use the service. Educational programs will be developed for high school and college undergraduate students, and will be a requisite for applying for observing time to ensure that the telescopes are used well.

We will investigate how to expand our participation in science fairs to encourage more students to conduct projects involving solar science. This support can include judging, mentoring, and providing some resources. NSO also is investigating programs with the Lodestar Planetarium in Albuquerque. Initial ventures will include public lectures on solar science and NSO providing wall graphics on solar physics with highlights on ATST and current research. We also are investigating the costs and production aspects of providing Spanishlanguage copies of literature to ensure that we reach our large Hispanic population.

4.5 Visitor Centers

NSO intends to develop a visitor center to be built at or near the ATST site. In the interim, NSO is gaining valuable experience from its existing visitor center at Sunspot and participation in the KPNO center on Kitt Peak.

The National Solar Observatory at Sacramento Peak hosts approximately 30,000 visitors annually. NSO visits begin at the Sunspot Astronomy and Visitor Center (Visitor Center), which was developed by funds from several state and federal organizations (scientists at NSO and the Air Force Research Laboratory, Apache Point Observatory, and the US Forest Service have designed the exhibits). These exhibits educate visitors on topics related to the science and research performed at NSO and Apache Point Observatory, and to astronomy topics in general, including the effect of the Sun on the Earth's environment. All visitors are encouraged to take a guided or self-guided tour of the facilities at NSO. Each year, the NSO gives approximately 120 guided tours for about 2000 participants, about half of whom are students, many Hispanic and Native American. NSO can provide tours in both English and Spanish. The Visitor Center has a gift shop that includes many educational materials about astronomy and provides all the necessary visitor conveniences. In 2003, we

anticipate completion of the live solar viewer that will project a white-light image of the Sun from a heliostat outside the Visitor Center to a screen inside the center.

A long-term goal is the inclusion of traveling exhibits (possibly through proposed membership with the Association of Science and Technology Centers) in related science fields such as space weather effects. In turn, NSO would develop traveling exhibits that could carry the message to audiences beyond the two Visitor Centers as well as offset the costs of renting other exhibits. This would help the Visitor Center expand our outreach, including repeat visitors (school groups in particular) from the region. Current solar physics exhibits in the Visitor Center need to be updated to inform visitors about advances in solar physics and in the technologies that enable new discoveries. A similar mechanism will be explored with the SCOPE group with the intent of developing shared exhibits.

The Visitor Center at Kitt Peak attracts more than 50,000 public visitors annually. The Visitor Center serves as the hub for visitor activities, providing information on its facilities and services to tourists on the mountain, including a large exhibit model of the McMath-Pierce solar telescope, a daily tour of the McMath-Pierce, and several colorful poster displays about NSO. Several NSO-related exhibits are being updated or newly developed, including a hands-on display about spectroscopy and its solar science applications.

4.6 NSO Public Web Pages

NSO actively promotes dissemination of interesting information to the public at large. A key mechanism for achieving this communication is the NSO Web site. The site provides information to the public on solar physics and astronomy, answers specific questions, and encourages readers to address fresh questions about science and astronomy. An "Ask Mr. Sunspot" forum provides a foundation for raising scientific curiosity. The ATST EPO officer or staff responds to these questions on a periodic basis, often on the day they are received. Scientists and the public at large are provided with near real-time solar imagery in the form of live Web-video feeds and movies of H\u03c4 images, solar surface magnetograms of the photosphere and chromosphere, and chromospheric and coronal imagery. Access of these images by educational institutions, the scientific community and the general public represents the most significant percentage of our Web traffic. A significant fraction of the images are from an historic digital archive. Access to this archive is one of the most prized services NSO offers to the world at large.

The Web pages are being expanded to include a wider range of current and historical images of work at NSO. The pages will be redesigned to accommodate user-friendly, searchable databases to help educators, students, and the news media readily access images and information. We also will start a program to provide drawings of the telescopes and instruments as image files, that students or the media can use with higher fidelity in publications.

5 MANAGEMENT PLAN

Achievement of NSO's science goals, through the implementation of the research and technical plan by its staff in collaboration with the community, requires an evolutionary change in NSO structure and its mode of operation. The restructured NSO requires the independence to develop and pursue its own program plans, manage its own budget, and seek its own alliances. In view of these imperatives, AURA has implemented a program to provide NSO with this required independence.

As NSO facilities and programs evolve, the fundamental structure of the NSO will evolve to ensure continued efficient and effective operations. NSO will continue to form strong collaborations to enhance both the long-term program and NSO's impact in strengthening the solar physics community as it undertakes the tasks outlined in its technical plan. NSO has formed major partnerships for the ATST, AO, ASP upgrade, and IR program and is actively seeking partners for the SOLIS network. NSO has continuing partnerships for ongoing telescope operations and data dissemination. The Management Plan describes the evolving NSO structure, the changing role and need to enhance the NSO scientific staff, NSO partnerships and leadership role, and evolving budgetary requirements.

5.1 Institutional Development

5.1.1 An Independent NSO

The NSO plan offers a critical mass of skills, a unique solar astronomy identity, and a clear management focus that will lead the community in developing the Advanced Technology Solar Telescope, provide state-of-the-art instrumentation, and meet the demands of solar and space researchers for high-quality synoptic data of solar variability and oscillations. The plan promotes strong collaboration between NSO, universities, and other government labs involved in solar research. NSO plans address the needs of US solar astronomy, taking into consideration the recommendations of the 1999 NAS/NRC report on ground-based solar astronomy (Parker Report), the 2001 Astronomy and Astrophysics Survey Committee's Decadal Survey, and the 2003 Solar and Space Physics Survey Committee's Decadal Research Strategy.

To fulfill these goals NSO has been established as a separate management unit within AURA with budget autonomy, except for some costs embedded in the NOAO program. The NSO Director reports directly to the AURA President. AURA also established a separate management council, the Solar Observatory Council (SOC), to oversee NSO management plans, and in particular the establishment of an independent NSO and ATST development. The membership of the SOC consists of experts in the areas of science, management and technical programs.

NSO has restructured its baseline resources to provide support for ATST development, SOLIS and GONG operations, and to ensure that the full scientific potential of adaptive optics and newly developed IR technologies are exploited on both existing and planned facilities to advance our understanding of the Sun. The NSO is taking the necessary steps to operate its major, future facilities with its allocation of NSF resources, without relying on partner institutions for baseline operations. NSO is in the process of developing a staffing plan to meet the increased demands these new facilities will generate. This management approach significantly contributes to ensuring the independence of the NSO even in the presence of multi-agency participation in its program. The NSO long-range plan implements the recommendations of the NRC Parker Report and Decadal Surveys and calls for operation of the current NSO facilities until the initiation of ATST operations. This plan reflects the high priority that has been associated with the high-resolution capabilities of the Dunn Solar Telescope, the IR capabilities of the McMath-Pierce

Telescope, the fact that these are among the world's premier solar facilities, and the need to use these telescopes as test-beds for ATST technology.

5.1.2 Implementing the Strategic Plan — the Evolution of NSO

NSO's strategic plan consists of implementing three closely integrated areas: science, technical, and educational outreach—plans for which are outlined in Sections 2, 3, and 4, respectively. NSO continuously assesses its planning in terms of users' needs, technology development, funding scenarios and opportunities, and the intellectual growth of its scientific staff. These four areas are closely linked; for example the quality of NSO support to the user community relies on implementing the latest technologies, which in turn depend on funds available and the innovation and initiative of the scientific staff. Recent examples of this initiative include adaptive optics, SOLIS development, GONG upgrades, and development of advanced polarimeter and narrowband imaging techniques in the visible and IR. The close interaction between staff scientists and the community drives the maximum utilization of existing facilities. Recent examples of this utilization include the application of the Advanced Stokes Polarimeter to sunspot structure and measuring prominence magnetic fields, narrowband imaging that reveals the nature of flows and magnetic fields in active regions, direct measurements of coronal magnetic fields, and the discovery and elucidation of the cool chromosphere in the infrared.

Figure 5.1-1 summarizes NSO's strategic plan, showing when new NSO capabilities will become operational and when older, replaced facilities may be phased out. Note that it is assumed in the figure that ATST construction will commence in 2006.

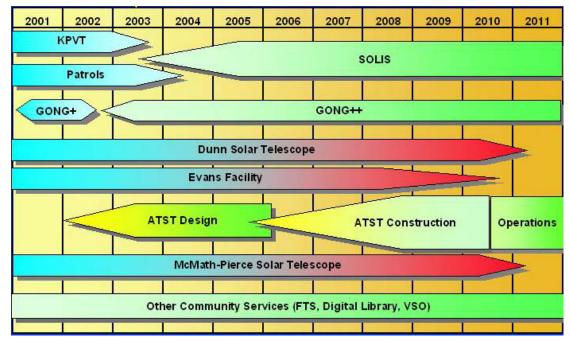


Figure 5.1-1. NSO Strategic Roadmap. Shows the planned evolution of facilities that NSO will operate from the beginning of the current decade to the end. ATST commissioning would occur in 2009 and scientific operations start in 2010.

Some of the critical-decision milestones include the following:

1. Commissioning of SOLIS (2003);

- 2. Selection of the ATST site (2003-4);
- 3. Funding of the ATST construction phase proposal (2006);
- 4. Decision on NSO headquarters location (2007-8);
- 5. Commissioning of the ATST (2010);
- 6. Relocation of SOLIS to the ATST site (2010);
- 7. Consolidation of the NSO (2010-11).

At each of these milestones, the value of existing facilities for solar astronomy will be weighed against freeing funds to complete high-priority programs in a timely fashion. NSO will solicit input from users through the Users' Committee and public meetings, such as the annual AAS/SPD business meeting, from the Solar Observatory Council, and from NSF, before making final decisions that broadly affect the community. NSO will strive to raise ATST funds without premature telescope closures that could eliminate entire areas of research in solar physics.

SOLIS data will replace the magnetograms, Dopplergrams, and spectral images currently obtained with the KPVT, the spectroheliograms obtained at the Evans Solar Facility, and the Sun-as-a-star spectral measurements made at the ESF and McMath-Pierce Telescope. After some period of overlapping observations (~6 months) required to calibrate the synoptic data sets, older programs will be terminated.

NSO's current operations, encompassing two major operational sites, Sacramento Peak in New Mexico and Tucson/Kitt Peak in Arizona, as well as several remote sites for the GONG network, address the needs of a diverse set of users in the solar community. The NSO maintains scientific staff at both of the major sites which greatly enhances the scientific return from these national facilities as outlined in Section 2. It is the close proximity of the staff to the telescopes that has yielded a wealth of evolving capabilities, thereby maintaining the NSO at the forefront of solar research. Through its adaptive optics, infrared, and advanced instrumentation projects, the current NSO program is highly invested in the future. The Dunn Solar Telescope, the McMath-Pierce and the Evans Solar Facility's coronagraph have all experienced renewed interest as manifested by strong proposal pressure as a direct result of these new capabilities. Maintaining scientific staff at both sites in the near-term will continue to provide the best support for the solar user community, the maximum scientific return from the facilities in both quality and quantity, and the most effective structure for developing the technologies needed to exploit the ATST. When the ATST becomes operational, the plan calls for consolidation of the NSO program to provide the most effective scientific utilization of its cornerstone facilities and the most efficient operations.

When the ATST becomes operational, it will far surpass the capabilities of both the McMath-Pierce Solar Telescope and the Dunn Solar Telescope. Given current operational budgets, NSO will have to decommission and close or transfer the operations of these telescopes to another organization. Realizing that the McMath-Pierce and the DST serve different user communities (McMath-Pierce: thermal IR, atmospheric physics, high-spectral resolution; DST: high-spatial resolution convection and magnetism), NSO anticipates that demand for ATST time will be highly over subscribed. The DST and McMath-Pierce would still be attractive test-beds for technology development and would still be capable of producing very interesting science. Consequently, the NSO plans to actively seek university or other groups that may be interested in their continued operation. The cost of operating telescopes at either Sacramento Peak or Kitt Peak as a remote site will depend critically on the available infrastructure.

Selection of the ATST site, coupled with approval of the construction phase proposal, will allow NSO to develop a plan for future NSO facilities and operations. Many of the issues NSO must address depend on

the final siting of the ATST. These include staff consolidation, size and location of observing and technical support staff, the need to build new facilities, the need to provide/purchase overhead functions (human resources, accounting, secretarial, computing, etc.), and the disposition of existing facilities. NSO is developing a comprehensive plan and cost for both consolidation and operations. These costs will be proposed to NSF as part of the NSO Long Range Plan in the next few years. Consolidation costs represent a one-time expense and will depend on the disposition of existing facilities and the procurement of new facilities. Consolidation should lead to some cost savings, which should help offset the costs that NSO will incur from providing its own overhead functions.

Depending on its location, operation of the ATST is envisioned as a remote operation, with a subset of the NSO staff. The remainder will locate at the NSO headquarters. Under this scenario, NSO can relocate its main organization to a location that provides the most benefit to U.S. solar physics. One particular goal is to increase university participation in solar physics. Both the Astrophysics and Astronomy Decadal Survey of the National Academy of Science and the NSF Astronomy Division view the ATST as a catalyst to reinvigorate the US program in solar physics. A necessary, key goal of this process is to increase the representation of solar physics in university faculties, thereby enhancing student participation in the field. The NSO is very interested in establishing close linkage with universities that are willing to develop strong programs in solar physics.

The ATST promises to push solar physics to the forefront of astrophysics by opening the exploration of new physical regimes that underlie solar magnetic activity and providing fundamental observational tests that challenge plasma and magnetic field theory. To provide the new talent needed to fully exploit these new capabilities, NSO wants to work closely with universities to increase the output of young solar physicists.

As part of consolidation, NSO will seek a relationship with one or more universities that results in the establishment of faculty positions emphasizing experimental/observational solar physics, and including a strong theoretical group. This may be accomplished through the establishment of a new joint program. NSO is examining several models of national laboratories aligned with universities to see if they might serve as a suitable model for a joint university-NSO relationship that includes one or more joint faculty/staff appointments.

In establishing a joint program and assigning teaching responsibilities, the target initiative of the NSO, namely, the enhancement of student participation in solar astrophysics and closely related fields (e.g., space physics) through teaching and student involvement in research at the undergraduate and graduate levels, must be a primary criterion. Presumably, a review period would be established to assess progress toward this goal.

NSO will coordinate the development of a restructuring plan with NSF.

5.1.3 Measuring Program Success

Metrics that measure the success of the NSO program fall into four major categories. (1) The leadership provided to the solar community for developing new scientific capabilities. (2) Service to the solar community by providing observing time on cutting edge, national solar facilities, improving their access to solar data, and service on national and international committees, review panels, editorial boards, and professional organizations. (3) Enhancing the scientific productivity of the NSO staff and its users. (4) The impact of its educational and public outreach programs. Some of the metrics AURA tracks to assess NSO's solar program are listed in Table 5.1-1.

Table 5.1-1. List of Metrics

Area	Metrics
Leadership in Solar Physics	1. ATST a. Completion of ATST site survey b. Completion of ATST D&D phase c. Development of funding partnerships for the ATST d. Submission & approval of ATST construction proposal 2. SOLIS a. Completion and deployment of SOLIS b. Formation of partnerships for SOLIS network c. Addition of SOLIS data to digital library and archive 3. GONG a. Implementation of GONG+ cameras b. Implementation of GONG++ data reduction 4. Adaptive Optics a. Development of high-order system b. Placement of system on all major facilities 5. Implementation of state-of-the-art instrumentation
Service to Solar Community	 a. Development of infrared detectors, filters, and spectrographs b. Implementation of narrowband filters c. Development of Advanced Stokes Polarimeter II 1. Provide observing time to the national and international solar community a. Increase support for remote observations b. Increase capability to provide quick-look and partially-reduced data c. Increase joint space/ground observing collaborations 2. Provide solar data to the solar, solar-terrestrial, atmospheric, space-weather and global climate communities a. Provide long-term synoptic observations of cyclic variation b. Provide solar activity observations c. Provide background observations for space missions
Scientific Productivity	1. Publications a. Refereed journals b. Other publications 2. Presentations a. Invited talks b. Meeting presentations
Education and Outreach	 Help train the future generation of solar astronomers Increase the number of graduate students trained Increase the number of postdoctoral candidates working at the NSO Improve the coordination with university programs Increasing the effectiveness of NSO K-12 programs Increase the number of teachers participating in the NSO RET program Increase the number of classroom exercises transitioned and supported Continued participation in local and minority schools Public relations (PR) Increase effectiveness of Web site Continue to upgrade Visitor Center Increase PR activities, press releases, support for NSF PR

5.2 Support for Users

5.2.1 User Interaction and Feedback

NSO serves a wide range of users from several disciplines with a remarkably broad range of pure and applied scientific research interests. From the basic structure of solar magnetic fields, to the forecasting of space weather, to the interior structure of the Sun, to the chemistry of the Earth's atmosphere—NSO provides critical observations and uses partnerships to leverage its resources.

The NSO Users' Committee, therefore, not only represents individual investigators, who will always remain at the core of NSO's scientific mission, but also has representatives from its major partner organizations. The current membership is given in Table 5.2-1. The Users' Committee meets formally twice a year and by teleconference as needed to advise the NSO Director and staff on user needs as well as on the short- and long-range planning for the observatory.

NSO disseminates information to the community through several channels. We fully participate in the NOAO/NSO and AAS Newsletters, maintain an up-to-date Web site, display at AAS and American Geophysical Union (AGU) meetings, and conduct a strong public outreach program. In addition, NSO reaches out to its communities through *SolarNews*, an on-line newsletter of the AAS Solar Physics Division (SPD); through presentation and discussion at meetings of the SPD, AAS and the AGU; associations with space programs such as Yohkoh, SoHO, Solar Mass

Table 5.2-1. NSO Users' Committee							
Name	Institution						
Tom Ayres, Ch.	University of Colorado						
Tom Berger	Lockheed-Martin						
Greg Ginet	Air Force Research Laboratory						
Phil Goode	New Jersey Institute of Technology						
Ernie Hildner	NOAA/Space Environment Center						
Don Jennings	NASA Goddard						
Phil Judge	High Altitude Observatory						
K. D. Leka	Colorado Research Associates						
Doug Rabin	NASA GSFC						
Ed Seykora	Eastern Carolina University						

Ejection Imager (SMEI), SOLAR-B, and participation in international programs such as the Solar-Terrestrial Energy Program.

It is also noteworthy that three NSO staff members (M. Giampapa, J. Leibacher, and T. Rimmele) are currently or recently served as elected members of the governing body of the Solar Physics Division. Leibacher is the current chair of the SPD. Jack Harvey is serving as an editor of the journal *Solar Physics*.

NSO's users receive funding from diverse sources, including three NSF divisions (Astronomical Sciences, Atmospheric Sciences, and Chemistry), universities, NASA, the US Air Force, the Office of Naval Research, the Department of Commerce (NOAA), and the Small Business Innovative Research (SBIR) program. NSO therefore maintains contact with many agencies and makes presentations to, and is often represented on, advisory groups such as the NASA Management Operations Working Group for Solar Physics and the NRC Committees on Solar and Space Physics and Solar-Terrestrial Research.

5.2.2 Telescope Allocations

To provide flexibility, responsiveness to users, and coordination with spacecraft and rocket experiments, NSO telescopes are scheduled quarterly. Site specific, but coordinated Telescope Time Allocation Committees (TACs) schedule time for NSO/Kitt Peak and NSO/Sacramento Peak. As the total number of hours scheduled is support-limited on most of the telescopes, there is typically an adjustment or

negotiation process (impractical in a nighttime context) for accepted proposals that results in a match between the days available and the days scheduled.

There are several differences between solar and nighttime telescope allocation. Most solar observations require coordinated data from several sources (space and ground), involve multi-instrument set-ups (e.g., simultaneous polarimetric, Doppler, and intensity imaging in several wavelengths using both spectrographs and narrowband filters), and the target is often the evolution of activity on the Sun which covers scales from milliseconds to weeks. Thus, NSO tends to allocate telescope time in blocks of two or more weeks. Another significant difference is the greater importance of daily or periodic observations in solar and solar-stellar research. Several of NSO's telescopes, including the Evans Solar Facility, the Kitt Peak Vacuum Telescope, and the Hilltop Facility, are primarily devoted to long-term, stable observations over the solar cycle. In addition, NSO provides support for operation of the AF Solar Optical Observing Network telescope located at Sacramento Peak. Such observations are critical to solar physics research programs as well as for the operational needs of NSO's partners and customers, including the US Air Force, NASA, and NOAA. Data from these programs are archived in the NSO Digital Library and are freely available over the Web. This library will expand greatly with the advent of SOLIS and the new high-resolution cameras on GONG.

Coordinated ground and space observations play an essential role in solar-terrestrial research. With the operation of the Solar and Heliospheric Observatory (SoHO) spacecraft and the Transition Region and Coronal Explorer (TRACE) missions, NSO has placed priority on its non-synoptic observing time to support observers participating in these missions. The appropriate TAC, however, reviews all proposals based on scientific merit.

Subarcsecond seeing or solar activity is often an essential requirement for some types of solar observations. Therefore, NSO scheduling makes a provision for "bumping" proposals that may temporarily displace ongoing programs when there are exceptional conditions.

5.2.3 Support at the Telescopes

Solar observations often involve very complex set-ups and operational needs. The NSO provides trained observing personnel to help the users successfully complete their set-up and to operate the telescope. NSO provides real-time quick-look capabilities to ensure data collection is proceeding as planned, and limited support for preliminary data reduction at the site. Host scientists are appointed as needed for visiting observers and become highly involved in ensuring a successful observing program.

5.3 NSO Scientific Staff

The responsibilities of a scientific staff member are divided between observatory service, scientific research, and educational outreach, but the primary role of the NSO scientific staff is to provide scientific and instrumental innovation. By doing so, the scientific staff provide critical support and leadership to the solar community. Experience clearly confirms the AURA management view that maintaining a strong NSO scientific staff, with active research interests, is required in order to provide US solar physicists with the best solar facilities in the world.

As stated in the Astronomy Decadal Survey, NSO plays an essential and effective role in supporting the solar physics community. The key to an effective national laboratory is the vigor and quality of its scientific staff. At both its operating locations in Sunspot and in Tucson, NSO maintains a scientific staff that is heavily involved in telescope operations, developing critical new instrumentation, providing observing and data support to the solar physics community, and conducting a vigorous research program.

While the current scientific staff is stretched very thin as NSO renews its major observing capabilities, the presence of co-located partner scientists and grant-supported research fellows at both sites provides a healthy scientific atmosphere. NSO and affiliated scientific staff are listed below, along with their primary area of expertise and key observatory responsibilities.

5.3.1 Sunspot-Based Scientific Staff

NSO Staff

- K. S. Balasubramaniam Solar activity; magnetism; polarimetry; Ch., NSO/SP Telescope Allocation Committee.
- Stephen L. Keil Director, solar variability, convection.
- Alexei A. Pevtsov Solar activity; coronal mass ejections.
- Thomas R. Rimmele Solar fine structure and fields; adaptive optics; instrumentation; ATST Project Scientist; Ch., Sac Peak Project Review Committee.
- Han Uitenbroek Atmospheric structure and dynamics; radiative transfer modeling of the solar atmosphere.

Grant-Supported Staff

- K. Sankarasubramanian Solar fine structure; magnetism; stokes polarimetry.
- Gilberto Moretto Optical instrumentation; adaptive optics.
- Maud Langlois (NJIT) Adaptive optics (high-order AO and multi-conjugate AO); instrumentation.

Air Force Research Laboratory Staff at Sunspot

- Richard C. Altrock Coronal structure and dynamics.
- Nathan Dalrymple Polarimetry; thermal analysis.
- Joel Mozer Coronal structure; remote sensing; space weather.
- Donald F. Neidig Solar activity; Project Scientist, Improved Solar Observing Optical Network (ISOON).
- Richard R. Radick Solar/stellar activity; adaptive optics.

5.3.2 Tucson-Based Scientific Staff

NSO Staff

- Mark S. Giampapa Deputy Director, stellar dynamos; stellar cycles; magnetic activity; Ch., Tucson Project Review Committee; SOLIS PI.
- John W. Harvey Solar magnetic and velocity fields, helioseismology, instrumentation; SOLIS Project Scientist; Ch., NSO/KP Telescope Allocation Committee.
- Frank Hill Solar oscillations; data management.
- Rachel Howe Helioseismology, the solar activity cycle.
- Christoph U. Keller Solar polarimetry; adaptive optics; instrumentation.
- Shukur Kholikov Helioseismology; data support.
- John W. Leibacher Helioseismology; GONG PI.
- Matthew J. Penn Solar atmosphere; solar oscillations; polarimetry; near-IR instrumentation.
- Jeffrey J. Sudol Helioseismology; data support.
- Clifford Toner Global and local helioseismology. Image restoration; data analysis techniques.

Grant-Supported Scientific Staff

- Michael Dulick Molecular spectroscopy; high-resolution Fourier transform spectrometry.
- Irene E. Gonzalez-Hernandez Helioseismology.
- Carl J. Henney Solar MHD; polarimetry; space weather.
- Rudolph W. Komm Helioseismology; dynamics of the convection zone.

- Elena Malanushenko Structure of the solar chromosphere and transition region; coronal holes.
- Roberta Toussaint Helioseismology; image calibration and processing; data analysis techniques.

NASA Staff in Tucson

• Harrison P. Jones – Solar magnetism and activity.

With the completion of new facilities and capabilities such as adaptive optics, SOLIS, GONG++, and ATST, the quality and quantity of NSO data and observational capabilities will be substantially enhanced. Taking advantage of these new facilities will require increased scientific efforts, continued development of new instrumentation, enhancement of the NSO digital library, and linkage to a virtual solar observatory. The permanent NSO scientific staff of 16 currently consists of 6 tenured astronomers (including the Director), 4 tenure-track astronomers, 1 senior scientist, and 5 support scientists.

Most of the senior scientific staff are deeply involved in projects (as seen from the staff list above). The immediate addition of four postdoctoral positions, two at each site, would substantially enhance the scientific output of the NSO staff. More importantly, it would begin training the next generation of solar observational scientists and provide a science cadre that can fully exploit the new capabilities provided by the ATST. We anticipate that many of the scientists filling these postdoctoral positions would eventually assume positions at universities, thus fulfilling one of the high priorities of the Astronomy Decadal Survey, i.e., to build-up the presence of solar physicists at universities.

The importance of having highly skilled observationalists who can take full advantage of ground-based facilities cannot be over emphasized. Ground-based observations have played key roles in the discovery and elucidation of many solar phenomena. Solar oscillations, magneto-convection, and sunspot structure and evolution, are just a few examples. In addition, ground-based observing facilities are vital to maintaining a productive space program. Instruments on many current space missions were first developed and tested at ground-based facilities. A vigorous program of ground-based solar observations provides the critical and complementary support of the scientific objectives of space missions. In particular, the longterm, highly flexible operation of ground-based facilities enable scientists to further investigate at high spectroscopic and polarimetric precisions the ultimate origins of the phenomena that are often revealed through satellite observations, typically at wavelengths that are inaccessible from the ground. For example, satellite missions operating at short wavelengths have unveiled the complex and dynamic structure that gives rise to the heating of the solar corona, as so vividly illustrated by the TRACE mission. However, it is complementary ground-based observations at high angular resolution that are the crucial next step toward an understanding of the origin of the corona. Specifically, the solar corona ultimately has its roots in the solar photosphere via the interactions between magnetic fibril field bundles and turbulent gas motions. The origin of the magnetic field itself is in the regenerative dynamo that operates in the solar interior. The ATST, SOLIS and GONG are designed to address these and other fundamental issues in solar physics.

The cost of adding four postdoctoral positions to the NSO staff would be approximately \$350K per year. In the longer-term, the NSO permanent scientific staff will need to grow by several positions to effectively support its new facilities. First we note that NSO scientists are expected to divide their time 50/50 between research and support activities. Based on the current level of scientific staff involvement and support for the Dunn Solar Telescope (DST) and McMath-Pierce Telescope (McMP) (approximately 8-10 FTEs), we estimate the ATST, which combines and expands the capabilities of these two facilities, will require from 13-15 science FTEs. Some of the current positions supporting DST and McMP operations are funded out of grants (e.g., adaptive optics, atmospheric chemistry, NASA thermal IR program) or are emeritus positions. We believe healthy operation of the ATST requires that the bulk of the support come from a permanent NSO staff. Based on our current synoptic program and digital library support, supporting SOLIS science, maintaining the digital library and supporting a connection to a virtual solar observatory will require five or

six scientists. GONG currently is supported by five full time and three partial science positions. Two of these are fully supported by NASA. While NSO can anticipate the continued presence of scientists from partner agencies, science support for its facilities should come primarily from NSO staff. Taking the lower numbers, we think the ideal NSO scientific staff should grow from its current 16 positions to about 26 positions in the ATST era. The technical and support staff needed to maintain and operate these facilities and capabilities will also grow. A very rough estimate of total budgetary growth would be 20 to 25% (real growth after correction for inflation).

NSO will develop a staffing plan over the next year that will accommodate the transition from operating its current facilities to those needed in the ATST era. As we begin operating SOLIS, gain more experience with GONG++, and develop an operational plan for ATST that will be part of the ATST construction proposal next year, the estimates of required staffing levels will become more accurate.

5.4 Community Partnerships and NSO Leadership Role

Through its operation of the majority of US ground-based solar facilities and its ongoing synoptic programs, NSO is clearly important to the solar community. In turn, NSO must closely work 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, solar adaptive optics, infrared observing capabilities in collaboration with NOAO, NASA and Michigan State University, and participation in the development of the Advanced Stokes Polarimeter with HAO. Table 5.4-1 lists several joint projects and development efforts.

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 will continue to work closely with this group in leading the successful completion of the design and planning for construction of the telescope. An ATST Science Working Group was formed to develop the detailed science requirements for the telescope.

Table 5.4-1. Joint Development Efforts								
Telescope/Instrument/Project	Collaborators							
Advanced Technology Solar Telescope	HAO, U. Hawaii, U. Chicago, NJIT, Montana State U., Princeton, Harvard/Smithsonian, UC-San Diego, UCLA,							
	U. Colorado, NASA/GSFC, NASA/MSFC, Caltech, Michigan State U., U. Rochester, Stanford, Lockheed-Martin, Southwest Research Institute, Colorado Research Associates, Cal State Northridge							
Adaptive Optics	NJIT, Kiepenheuer Institute							
Diffraction-Limited Stokes Polarimeter	HAO							
Synoptic Solar Measurements	USAF, NOAA, NASA							
Fourier Transform Spectrometer	NASA, U. Wisconsin							
Zürich Imaging Polarimeter	ETH-Zürich							
Near Infrared Magnetograph	NASA							
IR Spectrograph	U. Hawaii							
Solar Dual Image Motion Monitor	U. Chicago							

NSO established collaborations with NJIT and KIS to successfully obtain resources from the NSF/MRI program for the development of the high-order solar AO system. NSO personnel are now working closely with personnel from NJIT to design, build and test the system, which is essential to ATST development.

NSO and HAO have renewed their partnership to develop the next generation of the Advanced Stokes Polarimeter, the Diffraction-Limited Spectro-Polarimeter (DLSP). Together, they will develop an instrument that will be able to take advantage of the diffraction-limited images delivered by adaptive optics.

SOLIS is being developed by NSO to provide high-quality synoptic data to the community. While an NSO initiative, the SOLIS enterprise was highly endorsed by the solar community in both the NRC Parker Report and the Decadal Survey. NSO will assume leadership in forging alliances to expand SOLIS to a three-network system.

NSO leads a large consortium of scientists on the GONG project and has taken on the responsibility of upgrading the GONG network to provide data for the recently emerging field of local helioseismology for probing the solar interior near the surface.

NSO and NOAO share expertise in the development, acquisition and implementation of IR technologies for imaging and spectroscopic applications in astrophysics. The NSO received a 1024×1024 ALADDIN array at no cost from the NOAO development program to initiate a new and powerful IR camera system for solar astrophysics. NSO and NOAO staff consult on the technical aspects of this project, which serves as an example of the inter-Center cooperation, which AURA management fosters.

Finally, and as discussed in Section 4, NSO, in coordination with its ATST partners, is undertaking a vigorous expansion of solar outreach programs.

5.5 Operational Partnerships

NSO's strategic planning embraces the interdisciplinary nature and dual objectives of solar physics: 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.

NSO's mission to serve these communities, while remaining a scientific leader in solar physics, is critical because it is unique. NSO's solar telescopes are the largest and best instrumented in the world; NSO is unquestionably the dominant provider of ground-based solar observational facilities in the United States.

In accepting this significant responsibility, NSO has forged partnerships that strengthen its scientific and observational programs while satisfying partner needs. These partnerships range from long-term "residential" relationships to the cooperative development of individual instruments. In return, funding and co-located personnel from the partners permits NSO to operate a wider variety of instruments for longer periods that it could otherwise afford.

5.5.1 Air Force

The Air Force Research Laboratory (AFRL) maintains a staff of five to six scientists at NSO/Sacramento Peak. The AFRL program emphasizes studies of solar activity and activity prediction techniques,

advanced imaging, and development of new instrumentation. Air Force funding is provided for several synoptic programs and for the general operation of Sacramento Peak. AFRL ongoing programs include synoptic observation of coronal emission lines using the Evans Solar Facility coronagraph, observations of chromospheric heating and variability, studies of the Sun as a star, imaging of solar mass ejections with the Solar Mass Ejection Imager (SMEI), and use of the new ISOON flare patrol data to study prominence evolution and filament eruptions.

The Air Force program has provided funding for adaptive optics, development of narrowband filters, procurement of infrared cameras, and CCD cameras. The AF staff collaborates closely with NSO scientists on both science and instrument development. The Air Force Office of Scientific Research has expressed interest in the ATST and plans to maintain the Air Force solar research presence as NSO transitions to ATST operations.

Table 5.5-1. Current NSO Partnerships							
Partner	Program						
Air Force Research Laboratory	Solar Activity Research at NSO/SP; Telescope Operations; Adaptive Optics; Instrument Development; 6 Scientists Stationed at NSO/SP; Daily Coronal Emission Line Measurements; Provides Operational funding: \$400K-Base and Various Amounts for Instrument Development.						
NASA	KPVT Operations; Collaborative Science; SOLIS Development; Instrumentation; 1 Permanent Scientist; 1 Research Fellow at NSO/T; Operational Funding: \$32K for Telescope Operations and Various Amounts for Instrumentation.						
	McMath-Pierce: Support for Operation of the FTS; Upper Atmospheric Research.						
Office of Naval Research	Solar Activity Prediction; Support for KPVT Operations; 1 or 2 Postdocs Per Year.						
NSF Chemistry	FTS Facility Support						

5.5.2 NASA

The Laboratory for Astronomy and Solar Physics at NASA's Goddard Space Flight Center (GSFC) has cooperated with NSO for over twenty years in operating and developing the KPVT and is extending this effort to SOLIS. GSFC currently has one civil service scientist stationed in Tucson and, through competitive proposals, funds a second scientist and provides additional funding for KPVT operations. NASA obtains daily full-disk magnetograms and spectroheliograms for mission planning and scientific analysis plus rapid access to the KPVT for special observations. Many KPVT instrumentation projects have been partially funded through this cooperation including the current NSO/NASA spectromagnetograph, and current instrumentation funds are being used to procure components of the data and polarization modulation systems for SOLIS. Current research conducted by the NASA-supported staff focuses on use of the He I 1083 nm line as a diagnostic tool for solar mass loss and the association of magnetic features with solar irradiance variation.

A separate NASA proposal provides funding for operating, maintaining, and developing the Fourier Transform Spectrometer at the McMath-Pierce facility in support of upper atmospheric research conducted by scientists at several NASA centers (JPL, Langley, GSFC, and Ames). One full-time instrument observing associate is supported through this task.

5.5.3 Office of Naval Research (ONR)

The ONR Ocean, Atmosphere, and Space Science and Technology Department has a continuing interest in solar activity and its effects on naval operations. ONR fosters research in solar activity by means of grants to a few ground-based solar observatories. The data produced by the KPVT and spectromagnetograph has been of unique interest and ONR has supported research work at NSO to utilize this data set for more than a decade. The grants fluctuate in size from year to year and are used for salary and benefits support for young post-doctoral researchers to work in Tucson at a level of one or two per year. Previous researchers include Rudolf Komm, Sidney D'Silva, Yuhong Fan, and John Worden. Currently, Drs. Carl Henney and Roberta Toussaint are supported by an ONR grant.

The ONR grants are of great importance in improving the scientific output of the magnetograph facility on Kitt Peak. Other funding sources and partnerships primarily support operation of the facility but not scientific research. The leverage of the ONR grant allows an in-house research effort that otherwise would not be possible. The main focus of the present grant is improvement of the quality of the synoptic data, research into aspects of the solar magnetic field that have potential predictive capabilities, and development of new data products that test and extend our knowledge of the magnetic drivers of space weather. The focus in a new proposal will be on using new SOLIS data for studies of the vector magnetic field that have heretofore been impossible and on development of a test bench of numerical and physical models that claim predictive capability of solar activity.

5.5.4 NSF Chemistry

The purpose of the laboratory program funded by the NSF Chemistry Division is to provide access to the high-resolution Fourier Transform Spectrometer facility at the NSO McMath-Pierce for visiting investigators not directly associated with astronomical research, but rather to the areas of atomic and molecular laboratory spectroscopy.

Part of the research funded by this program is indirectly involved with astrophysical research in that it provides important spectroscopic information, such as line assignments and atomic or molecular constants, derived from spectra of atoms or molecules generated under laboratory conditions. This information assists astronomers in establishing the presence of these species in sunspots, stellar atmospheres, and interstellar clouds.

The largest portion of the research is primarily devoted to problems of physical and chemical interests. For example, an ongoing study by Lawler at the University of Wisconsin involves measuring the branching ratios of lanthanide atomic spectra with the objective of developing high-intensity and efficient lighting sources for commercial and industrial applications. Much of the emission work done on the spectra of transition-metal diatomics (oxides, nitrides, fluorides, and chlorides) with this instrument by Bernath (University of Waterloo), Davis (UC-Berkeley), and O'Brien (Southern Illinois University, Edwardsville) has led to a wealth of new information about the electronic structure of these molecules, which not only benefits astronomy, but is also of equal importance to the area of high-temperature chemistry.

It should be noted that the combination of the high-resolution FTS coupled to a large solar telescope with infrared capability makes this facility ideally suited for research involving the chemistry of the atmosphere of the Earth.

5.6 NSO Organization

Currently, NSO is divided into three functional units, NSO/Sacramento Peak (NSO/SP), NSO/Tucson (NSO/T), and NSO/GONG. NSO also has project groups conducting high-order AO, SOLIS and ATST, all of which have a mixture of NSO and separate funding. NSO currently has 69 positions funded from its NSF base program. An additional 39 employees work at NSO and are funded by NSF projects (AO, ATST and SOLIS), the Air Force, NASA, NJIT and other partner institutions. In addition, NSO shares support personnel (e.g., shops, facilities maintenance, computing, administration) with NOAO in Tucson and on Kitt Peak. Funds for these shared services are in the NSO budget and shown on the NSO spending plan (Section 5.7), but they are currently committed to NOAO for shared services, which result in considerable cost savings.

The NSO Director's office consists of two employees, the Director and an executive assistant. The Director currently resides at NSO/SP. A site director for NSO/T also serves as deputy director and oversees operations at Tucson. The Director tries to spend approximately one week a month in Tucson. NSO/SP has a site administrator for operations and facilities. In addition, the NSO Director shares support personnel with NOAO for accounting, human resources, graphics, educational outreach, etc.

NSO/SP operates several telescopes on Sacramento Peak in New Mexico as well as office, computing, instrument development and housing facilities for visitors and the resident scientific and technical staff. Major projects at NSO/SP include development of adaptive optics, development and deployment of the site-survey instruments for the ATST and work on the ATST design. In addition, NSO/SP conducts experiments and minor projects to improve near-IR cameras and spectroscopy, narrowband imaging in the visible and IR, and vector polarimetry techniques that can take advantage of high-resolution facilities. Currently there are 46 personnel at NSO/SP. There are 32 NSF base-funded employees, 6 USAF funded scientists, three research fellows and a Ph.D. thesis student funded as part of the AO effort, which is funded both from the NSO base and from the NSF/MRI Adaptive Optics program through NJIT. One ATST project funded employee and two funded by the AF ISOON project reside at Sunspot. Funding for one instrument maker is currently shared between NSO, the nearby Apache Point Observatory, and various projects. In addition, a PhD student from Utah State University and a Masters student from New Mexico Institute of Technology will spend a few months per year at Sacramento Peak. They will soon be joined by a student from the University of Rochester who is doing her PhD thesis with support from an ATST graduate student fellowship.

NSO/T operates the solar telescopes on Kitt Peak, offices in Tucson, and conducts projects at the Tucson facilities. NSO shares support personnel with KPNO on Kitt Peak and with the other NOAO divisions in Tucson. Major projects at NSO/T include SOLIS, large-format IR camera development, and work on the ATST site survey and design. NSO/T also conducts experiments and minor projects to improve Stokes polarimetry techniques, solar-stellar observation techniques, and speckle imaging techniques. NSO/T has 16 NSF-funded staff, 6 NSO employees funded by SOLIS, two funded by NASA and two funded by ONR. There are currently 8 employees in Tucson working for the ATST project, including the program manager.

NSO/GONG operates and maintains the GONG network of 6 telescopes, collects, processes and provides data to the users. NSO/GONG has just completed upgrading the GONG cameras and is implementing GONG++ high-resolution operations. NSO/GONG currently has 21 NSO employees and 2 employees funded by NASA.

As NSO fully establishes independent operations and begins development of the ATST, the management structure will evolve over the next few years. When the ATST is completed, NSO will completely reorganize and consolidate its resources.

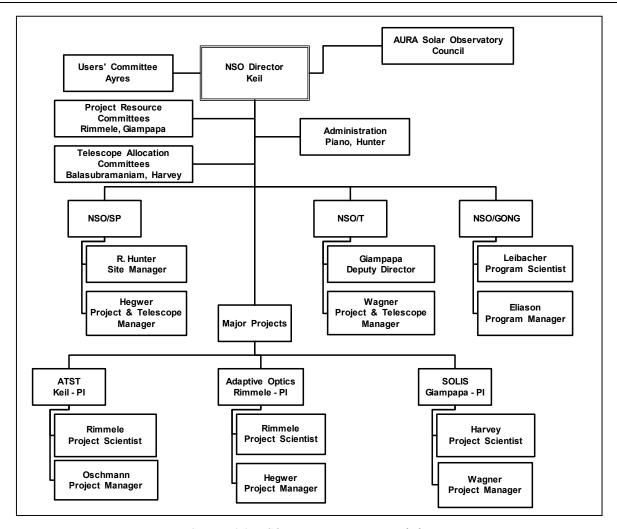


Figure 5.6-1. NSO summary organizational chart.

5.7 NSO Spending Plan

To support the solar community with observational facilities and to implement the technical program plan presented in Section 3, NSO has developed the 5-year spending plan shown in Tables 5.7-1 and 5.7-2. The plan covers a five-year period beginning in FY 2003. Using a zero-based budget approach, the budget is summarized by functional units in Table 5.7-1 and shown in detail with each functional unit broken into work areas in Table 5.7-2. This approach considers the tasks required to a) support the user community at the NSO telescopes as well as users of NSO data products; b) implement the initiatives discussed in Section 3; c) operate the evolving facilities shown in Figure 5.1-1; and d) conduct research.

The NSO spending plan reflects the evolution of ongoing programs as efforts to develop ATST technology increases with time. Funding for the proposed program enhancements are explained below.

The NSO budget is allocated to the various tasks NSO must perform to fulfill its mission. The actual allocation occurs in functional units (NSO/SP, NSO/T, GONG, and the Director's Office) as a means of assigning responsibility and budget authority. This funding is then subdivided into operations, projects and support functions. A single program manager will control the associated budget for projects with crossfunctional areas. In addition, separate budgets are assigned to the major projects (currently ATST, adaptive optics, and SOLIS), much of which comes from additional proposal-generated funding outside the NSO base. Each of the major projects has a project manager responsible for the budget and schedule.

Table 5.7-1. Five-Year Spending Summary

(In Thousands of Dollars)

<u>-</u>	FY2003	FY2004	FY2005	FY2006	FY2007
Director's Office	288	300	309	319	328
Tucson Operations	1.403	1.536	1.532	1.528	1.523
Sacramento Peak Operations	1.586	1.621	1,620	1,618	1,667
ATST In-House Contribution	814	942	1,070	1,202	1,288
GONG	2,330	2,408	2,480	2,555	2,632
SOLIS	300	300	309	318	328
Base Budget Program Totals	6,722	7,107	7,320	7,540	7,766
General NOAO Support	1,060	1,091	1,124	1,158	1,193
Management Fee	175	202	208	214	220
Base NSO Program	7,956	8,400	8,652	8,912	9,179
ATST					
AST ATST D&D Proposal	2,384	2,500	2,624		
ATST ATM Funding	200	200	200		
ATST Mirror Increment		1,172			
ATST Construction Proposal				62,894	44,280
Base NSO + ATST	10,540	12,272	11,476	71,806	53,459
Proposed Program Enhancements					
ATST Mirror Increment		828			
ATST Environmental Assessment		400	400		
NSO Salary Adjustments	90	100	105	115	125
Postdoctoral Fellows	87	174	262	350	350
Staff Augmentations			300	500	1,000
Deferred Maintenance	50	300	100	100	
EPO Officer		100	108	116	120
Total Proposed Budget	10,767	14,174	12,751	72,987	55,054

The spending plan assumes ATST development will have two funding components, in-house contributions from NSO and project funds resulting from the ATST proposal submitted to NSF. The funds shown in Tables 5.7-1 and 5.7-2 as ATST in-house contribution represent a reallocation of NSO base funding to the ATST project. Under a separate ATST proposal submitted to NSF in December 2000, the NSO was to receive an increment of \$1,100K in FY 2001, and \$1700K in FY 2002, \$2700K in each of FYs 2003 through 2005 for the ATST design and development effort. The NSF Astronomical Sciences Division, provided \$900K in FY 2001, \$1400K in FY 2002, and \$2376K in FY 2003, and plans to provide \$2,500K in FY 2004 and \$2,624K in FY 2005 for ATST design and development. The Atmospheric Sciences Division provided \$200K in each fiscal year from FY 2001 through FY 2003 and plans to provide \$200K in FY2004 and FY2005 to support HAO's participation in the ATST development effort. A substantial fraction of the ATST D&D budget will go to the other collaborating institutions for instrument design and to help conduct the ATST site survey. NSO base funds will partially cover the design and development of an AO system for the ATST, development of IR technologies, and site-testing instrumentation and operations carried out by the NSO. These NSO base funds represent a substantial and necessary part of the ATST program, and were accounted for when the ATST budget proposal was developed. The FY 2004 budget contains funding for the purchase of the ATST mirror blank and an increment to fund environmental impact assessments of the top ATST site(s). As noted in Section 3.1.1, the mirror blank has been identified as the major item that will determine the ATST schedule. Its early purchase reduces cost, expedites the schedule and reduces overall project risk.

Although we allocate the base budget through functional areas, the actual budget is developed from the tasks in our work breakdown structure. Table 5.7-2 shows each of the functional areas broken down by work areas. Funding for the support received from NOAO in Tucson is listed separately because it is embedded in the NOAO budget. Approximately 17% of the NOAO support goes to computer support, 33% to facilities in Tucson, 8% to educational outreach, and 42% to business service and human resource support.

Table 5.7-2. Detailed Five-Year Spending Plan (In Thousands of Dollars)

	FY20	003	FY20	004	FY	2005	FY2	2006	FY2	2007
Director's Office										
Director's Office	306		318		328		338		348	
Programmed Indirects	(18)	_	(18)		(18)		(19)	i	(20)	
Total Director's Office	-	288		300		309		319		328
Tucson Operations										
Scientific Staff	772		745		718		689		660	
Software Support	178		183		189		195		200	
Instrument Development	196		340		350		360		371	
NOAO/ETS Support	102		105		108		111		115	
Telescope Operations ⁽¹⁾	144		150		154		159		164	
Utilities on KP ⁽¹⁾	43		44		46		47		48	
Educational Outreach ⁽²⁾	40		40		40		40		40	
Revenue	(72)		(72)		(73)		(74)		(75)	
Total NSF Tucson		1,403		1,536		1,532		1,528		1,523
Sacramento Peak Operations										
Scientific Staff	412		374		335		295		304	
Scientific Support/Computing	273		279		289		298		308	
Instrument Development/Maintenance	399		454		467		481		496	
Telescope Operations	173		185		191		197		203	
Facilities	607		616		634		653		673	
Administrative Support	228		235		242		249		257	
Educational Outreach ⁽²⁾	130		130		132		133		135	
Revenue ⁽³⁾	(637)		(652)		(670)		(689)		(708)	
Total NSF Sac Peak		1,586	<u> </u>	1,621		1,620		1,618		1,667
ATST In-House Contributions										
ATST Fellow ⁽⁴⁾	20		87		141		145		150	
ATST Science Support	-		100		203		309		368	
Technology Development ⁽⁵⁾	534		705		726		748		770	
In-House Site Testing	260		50		-		-		-	
Total ATST		814		942		1,070		1,202		1,288
GONG										
Scientific Staff ⁽⁶⁾	290		317		326		336		346	
DMAC Operations Telescope Operations	933 929		947 968		975 997		1,004 1,027		1,035 1,058	
Administrative Support	178		177		182		1,027		1,038	
Total NSF GONG	170	2,330	177	2,408	102	2,480	100	2,555	193	2,632
Total NSI GONG		2,330		2,400		2,400		2,333		2,032
SOLIS										
Construction (In-House)	100		-		-		-		-	
Operations	200	_	300		309		318	,	328	
Total SOLIS		300		300		309		318		328
NOAO Business/EO Support		1,060		1,091		1,124		1,158		1,193
Management Fee		175		202		208		214		220
Total Base Program	•	7,956	_	8,400	-	8,652		8,912	•	9,179
ATST										
AST ATST D&D Proposal		2,384		2,500		2,624				
ATM ATST D&D Proposal		200		200		200				
ATST Advanced Mirror Purchase				1,172						
ATST Construction Proposal				,				62,894		44,280
Total Funding	•	10,540	_	12,272	-	11,476	•	71,806	-	53,459
Requested Deltas (7)										
ATST Mirror				828						
ATST Environmental Assessments				400		400				
NSO Salary Adjustments		90		100		105		115		125
Postdoctoral Fellowships		90 87		174		262		350		350
Staff Augmentations		01		1/4		300		500		1,000
Deferred Maintenance/Upgrades		50		300		100		100		.,000
EPO Position		30		100		108		116		120
Requested Total	•	10,767	_	14,174	-	12,751	•	72,987	-	55,054
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Notes for Table 5.7-2:

- (1) Includes NSO personnel and direct-billed utilities only. Mountain support for maintenance, roads, etc. is included in the KPNO budget and not accounted for here. Estimates of this support range from \$200K-500K, depending on how mountain support is divided among the various telescopes and operations.
- (2) The educational outreach amounts contain funds from the REU and RET programs, and the NSO Visitor Center, which provides both public and educational outreach. The Visitor Center is basically self-sustaining; NSO uses the conference center, provides maintenance and budgets, and a small amount for contingencies. REU/RET funds are provided separately from the NSO base budget and are included in the revenue lines.
- (3) Revenues in Tucson include \$32K from NASA and \$40K from the REU/RET program. Sac Peak revenues include meal revenues (\$16K), housing revenues from rent (\$91K), funds received from the Air Force for operations (\$400K), earnings at the Visitor Center gift shop (\$50K), and from the REU/RET program (\$40K). Funds received from the Air Force (AF) are variable due to DoD budget variations and are negotiated annually. While NSF charges ~5% overhead, this is always returned to NSO from the AST Division under the MOU with the AF; thus there is no reduction in the amount available to NSO.
- (4) In FY 2003 this position is cost shared with AURA and hopefully can be cost shared in subsequent years.
- (5) This number includes NSO technical and scientific staff who are devoting time to the ATST science definition, the development of ATST technologies, instruments and the site survey. Its growth accounts for the reduction in scientific staff funding in the existing operating units as staff members devote increasing amounts of time to ATST.
- (6) Three of the scientists accounted for in Tucson operations also devote considerable time to GONG.
- (7) These deltas, explained in the text below, are requests needed to ensure maximum productivity and impact of current NSO facilities and programs.

Budget Increments

In addition to the current NSO program, Tables 5.7-1 and 5.7-2 also contain proposed budget increases, beyond inflation, needed to continue effective support for the solar community with current facilities and to position NSO to operate the new facilities, which will require increased levels of effort because of their greatly enhanced capabilities and complexity. The numbers reflect the increases called for in the scientific staffing plan (Section 5.3). The requested deltas assume NSO will receive the revised budget awarded in the AURA proposal for management of NSO and NOAO (\$12,850K in FY 2004) as a base.

Specific justifications for the deltas (listed in priority order) include:

- Advanced mirror purchase and environmental assessments (see Section 3.1.1).
- Postdoctoral fellows and staff augmentation (see Section 5.3.1).
- Increase in NSO salaries, which have fallen substantially behind the university community and the other AURA centers. More competitive salaries are needed to maintain the staffing levels to meet NSO's increasing obligations. The proposed NSO-NOAO split of the President's budget will permit NSO to provide an ~3%-raise in FY 2003. According to AURA's salary survey, NSO scientific staff salaries are low by 10-20% and technical and administrative staff salaries by 5-10%. NSO needs to address this issue, or risk losing key members of its staff.
- Deferred maintenance. Both NSO sites have deferred maintenance and upgrades in favor of putting NSO resources into new projects. Both the Dunn Solar Telescope and McMath-Pierce Solar Telescope need some investment in visible and IR camera systems, telescope control systems, and some critical maintenance items to keep them performing at a level needed to provide quality data to the solar community. NSO/Sac Peak needs to upgrade its sewage plant, repave some roads, repaint many of the structures, and bring housing electrical systems up to code to keep a viable infrastructure that supports the DST and other observing facilities.
- The EPO increment is to support an educational outreach officer responsible for supervising and implementing the programs discussed in Section 4. His/her efforts will be coordinated with the ATST EPO effort. Currently, most of the responsibility for EPO resides with the scientific and administrative staff. The EPO officer would coordinate and increase the effectiveness of staff efforts and enable the scientific staff to devote more time to research.

FY 2003 Budget

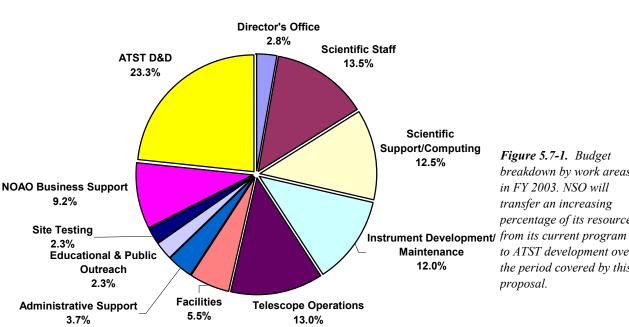
The detailed breakdown of the NSO budget for FY 2003 by work area and functional unit is shown in Table 5.7-3. This is a revision of the budget submitted in the Program Plan for FY 2003 and reflects the \$10,400K (\$8,000K base and \$2,400K for the ATST from NSF/AST and \$200K from NSF/ATM) in the recompetition award less the 0.65% rescission. The upper part of each table shows the projected total NSO funding including proposals, revenues, and partner funding, while the bottom removes revenues and proposals, showing the base NSF funding for the ongoing base NSO program.

Table 5.7-3. Final FY 2003 Budget

(In Thousands of Dollars)

	Director's						Total
	Office	Sunspot	Tucson	GONG	ATST	SOLIS	Budget
Director's Office	306						306
Scientific Staff		412	772	290	20		1,494
Scientific Support/Computing		273	178	933			1,384
Instrument Development/Maintenance		399	298	-	534	100	1,330
Telescope Operations		173	144	929		200	1,447
Facilities		607					607
Administrative Support		228		178			406
Educational & Public Outreach	84	130	40				254
Site Testing					260		260
NOAO Business Support	54	159	467	339			1,019
ATST D&D					2,584		2,584
AURA Management Fee	175						175
Total Program	619	2,381	1,899	2,669	3,397	300	11,267
Revenues					(0.00.1)		
NSF ATST D&D Proposal (AST Div)					(2,384)		(2,384)
NSF ATST D&D Proposal (ATM Div)					(200)		(200)
Programmed Indirects	(18)						(18)
Housing Revenue		(91)					(91)
Meal Revenue		(17)					(17)
NSF REU/RET Funding		(40)	(40)				(80)
AF Support		(439)					(439)
NASA Support			(32)				(32)
Visitor Center Revenue		(50)					(50)
NSF Funds - ATST	601	1,745	1,827	2,669	814	300	7,956

Figure 5.7-1 shows the percentage breakdown for the total NSO program in FY 2003. The figure shows that the ATST is now the dominant NSO program.



NSO FY2003 Budget Summary

Figure 5.7-1. Budget breakdown by work areas in FY 2003. NSO will transfer an increasing percentage of its resources to ATST development over the period covered by this proposal.

FY 2004 Budget

The FY 2004 budget proposed in the revised recompetition proposal (\$12,850K) is shown in Table 5.7-4. This budget provides for an ~3% inflationary increase in NSO salaries with some small market adjustments, purchase of a mirror blank for the ATST, and funding of the ATST D&D effort at the level in the revised D&D proposal. To bring this down to the level of the President's budget for NSO (\$12,000K), we need to lower ATST spending by \$200K, allocate only \$1.5M for the mirror procurement, and reduce the base to \$8,172K. If the other ~\$500K needed for the mirror procurement can be found in the FY 2003 budget, this would not be a major impact on the NSO program. The main impacts would include limiting the NSO salary adjustment and deferring some of the work on the ATST design.

Table 5.7-4. Preliminary FY 2004 Budget

(In Thousands of Dollars)

	Director's						Total
	Office	Sunspot	Tucson	GONG	ATST	SOLIS	Budget
Director's Office	318						318
Scientific Staff		374	745	317	187		1,623
Scientific Support/Computing		279	183	947			1,409
Instrument Development/Maintenance		454	445	-	705	-	1,603
Telescope Operations		185	150	968		300	1,603
Facilities		616					616
Administrative Support		235		177			412
Educational & Public Outreach	87	130	40				256
Site Testing					50		50
NOAO Business Support	55	164	481	349			1,049
ATST Mirror Procurement					1,172		1,172
ATST D&D					2,700		2,700
AURA Management Fee	202						202
Program Total	460	2,436	2,044	2,757	4,814	300	13,013
Revenues							
NSF ATST D&D Proposal (AST Div)					(2,500)		(2,500)
NSF ATST D&D Proposal (ATM Div)					(200)		(200)
NSF ATST Mirror Procurement					(1,172)		(1,172)
Programmed Indirects	(18)				(1,112)		(1,172)
Housing Revenue	(10)	(91)					(10) (91)
Meal Revenue		(17)					(17)
NSF REU/RET Funding		(40)	(40)				(80)
AF Support		(454)	(70)				(454)
NASA Support		(7 0 4)	(32)				(32)
Visitor Center Revenue		(50)	(32)				(5 <i>2)</i> (5 <i>0</i>)
NSF Funds - ATST	442	1,785	1,972	2,757	942	300	8,400

FY 2005 - FY 2007 Budgets

Tables 5.7-5 through 5.7-7 show preliminary detailed budgets for the out years. They reflect cost for operation of current facilities and a gradual shifting of scientific and project efforts to the ATST.

Table 5.7-5 FY 2005 Preliminary Budget

(In Thousands of Dollars)

	Director's						Total
	Office	Sunspot	Tucson	GONG	ATST	SOLIS	Budget
Director's Office	328						328
Scientific Staff		335	718	326	344		1,723
Scientific Support/Computing		289	189	975			1,453
Instrument Development/Maintenance		467	458	-	726		1,651
Telescope Operations		191	154	997		309	1,651
Facilities		634					634
Administrative Support		242		182			424
Educational & Public Outreach	89	132	40				261
Site Testing					-		-
NOAO Business Support	57	169	495	360			1,081
ATST D&D					2,824		2,824
AURA Management Fee	208						208
Program Total	681	2,458	2,054	2,840	3,894	309	12,237
Revenues							
NSF ATST D&D Proposal (AST Div)					(2,624)		(2,624)
NSF ATST D&D Proposal (ATM Div)					(200)		(200)
Programmed Indirects	(18)						(18)
Housing Revenue		(94)					(94)
Meal Revenue		(17)					(17)
NSF REU/RET Funding		(40)	(40)				(80)
AF Support		(467)					(467)
NASA Support			(33)				(33)
Visitor Center Revenue		(52)					(52)
NSF Funds - ATST	663	1,788	1,981	2,840	1,070	309	8,652

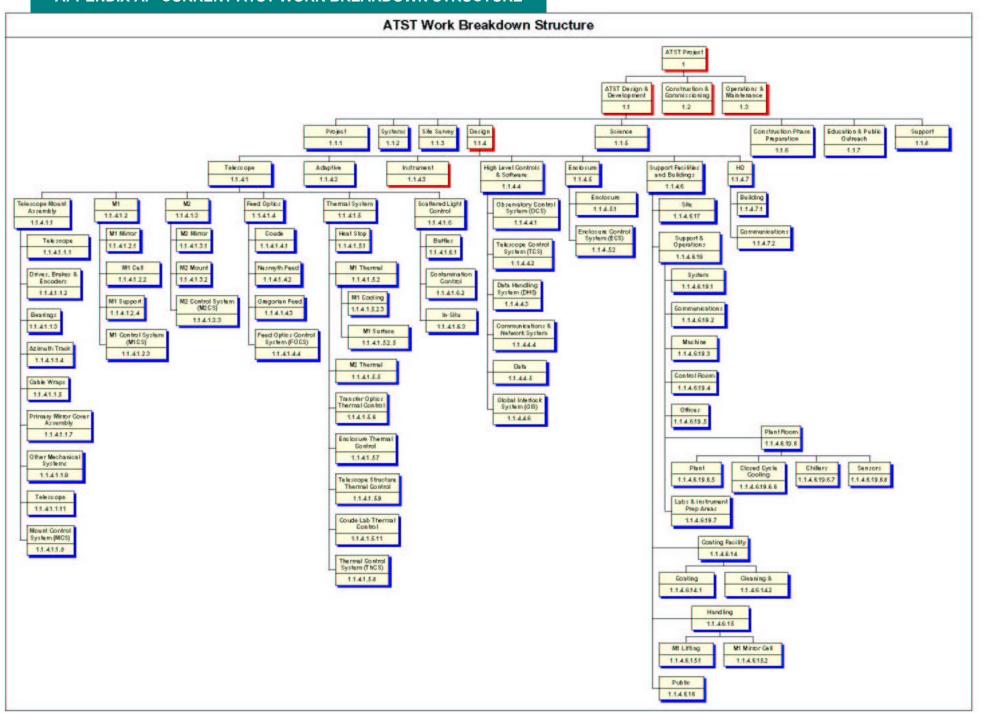
Table 5.7-6. FY 2006 Preliminary Budget (In Thousands of Dollars)

	Director's						Total
	Office	Sunspot	Tucson	GONG	ATST	SOLIS	Budget
Director's Office	338						338
Scientific Staff		295	689	336	454		1,775
Scientific Support/Computing		298	195	1,004			1,497
Instrument Development/Maintenance		481	472	-	748	-	1,701
Telescope Operations		197	159	1,027		318	1,701
Facilities		653					653
Administrative Support		249		188			437
Educational & Public Outreach	92	133	40				265
Site Testing					-		-
NOAO Business Support	59	174	510	371			1,113
ATST D&D					62,894		62,894
AURA Management Fee	214						214
Program Total	702	2,481	2,065	2,925	64,096	318	72,587
Revenues							
NSF ATST D&D Proposal (AST Div)					(62,894)		<i>(62,894)</i>
NSF ATST D&D Proposal (ATM Div)					0		0
Programmed Indirects	(19)						(19)
Housing Revenue		(97)					(97)
Meal Revenue		(18)					(18)
NSF REU/RET Funding		(40)	(40)				(80)
AF Support		(481)					(481)
NASA Support			(34)				(34)
Visitor Center Revenue		(53)					(53)
NSF Funds - ATST	683	1,792	1,991	2,925	1,202	318	8,912

Table 5.7-7. FY 2007 Preliminary Budget (In Thousands of Dollars)

	Director's						Total
	Office	Sunspot	Tucson	GONG	ATST	SOLIS	Budget
Director's Office	348						348
Scientific Staff		304	660	346	518		1,828
Scientific Support/Computing		308	200	1,035			1,543
Instrument Development/Maintenance		496	486	-	770	-	1,752
Telescope Operations		203	164	1,058		328	1,752
Facilities		673					673
Administrative Support		257		193			450
Educational & Public Outreach	95	135	40				270
Site Testing					-		-
NOAO Business Support	60	179	526	382			1,147
ATST D&D					44,280		44,280
AURA Management Fee	220						220
Program Total	723	2,554	2,075	3,013	45,568	328	54,262
Revenues							
NSF ATST D&D Proposal (AST Div)					(44,280)		(44,280)
NSF ATST D&D Proposal (ATM Div)					0		0
Programmed Indirects	(20)						(20)
Housing Revenue		(99)					(99)
Meal Revenue		(18)					(18)
NSF REU/RET Funding		(40)	(40)				(80)
AF Support		(496)					(496)
NASA Support			(35)				(35)
Visitor Center Revenue		(55)					(55)
NSF Funds - ATST	703	1,846	2,000	3,013	1,288	328	9,179

APPENDIX A. CURRENT ATST WORK BREAKDOWN STRUCTURE



APPENDIX B. ACRONYM GLOSSARY

AAS American Astronomical Society

AASC Astronomy and Astrophysics Survey Committee

AFRL Air Force Research Laboratory AGU American Geophysical Union

AO Adaptive Optics

ASWG ATST Science Working Group

ATST Advanced Technology Solar Telescope ATM Atmospheric Sciences (Division of NSF)

AURA Association of Universities for Research in Astronomy, Inc.

BBSO Big Bear Solar Observatory

CD-ROM Compact Disk – Read Only Memory

CMEs Coronal Mass Ejections
CoDR Concept Design Review
D&D Design & Development

DLSP Diffraction-Limited Spectro-Polarimeter

DMAC Data Management and Analysis Center (GONG)

DST Dunn Solar Telescope

EGSO European Grid of Solar Observations

EIS Environmental Impact Studies

EIT Extreme ultraviolet Imaging Telescope (SoHO)

EPO Educational and Public Outreach

ESF Evans Solar Facility EUV Extreme Ultraviolet

ETH-Zürich Eidgenössische Technische Hochschule-Zürich

FDP Full Disk Patrol FTEs Full Time Equivalents

FTS Fourier Transform Spectrometer

FY Fiscal Year GB Giga Bytes

GONG Global Oscillation Network Group GSFC Goddard Space Flight Center (NASA)

HAO High Altitude Observatory

IAC Instituto de Astrofisica de Canarias

ICD Interface Control Document

IR Infrared

ISOON Improved Solar Observing Optical Network

ISS Integrated Sunlight Spectrometer
KIS Kiepenheuer Institute for Solar Physics

KPNO Kitt Peak National Observatory KPVT Kitt Peak Vacuum Telescope

LRP Long Range Plan

LWS Living with a Star (NASA)

McMP McMath-Pierce

MDI Michelson Doppler Imager (SoHO)

MHD Magnetohydrodynamics MOU Memorandum of Agreement

MRI Major Research Instrumentation (NSF)

NAS National Academy of Sciences

NASA National Aeronautics and Space Administration

APPENDIX B. ACRONYM GLOSSARY

NDSC Network for the Detection of Stratospheric Change

NJIT New Jersey Institute of Technology

NOAA National Oceanic and Atmospheric Administration

NOAO National Optical Astronomy Observatory

NRC National Research Council NSF National Science Foundation

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

ONR Office of Naval Research

PAEO Public Affairs and Educational Outreach

PFB Pre-flare Brightening

PSPT Precision Solar Photometric Telescope
RBSE Research-Based Science Education
RET Research Experiences for Teachers
REU Research Experiences for Undergraduates
RISE Radiative Inputs of the Sun to Earth
SBIR Small Business Innovative Research

SCOPE Southwest Consortium of Observatories for Public Education

SCTs Schmidt-Cassegrain Telescopes SDO Solar Dynamics Observatory

SEC Space Environment Center (NOAA)

SMEI Solar Mass Ejection Imager

SOAR SOuthern Astrophysical Research (Telescope)

SOC Solar Observatory Council

SoHO Solar and Heliospheric Observatory

SOI/MDI Solar Oscillations Investigations/Michelson Doppler Imager (SoHO)

SOLIS Synoptic Optical Long-term Investigations of the Sun

SPD Solar Physics Division (AAS)
SRA Summer Research Assistant
SRD Science Requirements Document
SSWG Site Survey Working Group (ATST)
STEP Summer Teacher Enrichment Program

SXT Soft X-Ray Telescope

TAC Telescope Time Allocation Committee

TB Tera Bytes

TLRBSE Teacher Leaders in Research Based Science Education

TRACE Transition Region and Coronal Explorer

USAF United States Air Force

UV Ultraviolet

VSM Vector Spectromagnetograph VSO Virtual Solar Observatory WBS Work Breakdown Structure

WWW World Wide Web

Yohkoh "Sunbeam," Satellite project of the Japanese Institute of Space and Astronautical Sciences

ZIMPOL Zürich IMaging POLarimeter