









NSO

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MISSION

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

NSO accomplishes this mission by:

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

RESEARCH OBJECTIVES

The broad research goals of NSO are to:

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

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1 EXECUTIVE SUMMARY

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

Major components of the National Solar Observatory strategic planning include:

- Developing the 4-meter Daniel K. Inouye Solar Telescope (DKIST) on behalf of, and in collaboration with, the solar community.
- Operating a suite of instruments comprising the NSO Integrated Synoptic Program (NISP). This includes the Synoptic Optical Long-term Investigation of the Sun (SOLIS) and the Global Oscillation Network Group (GONG).
- An orderly transition to a new NSO structure, which can efficiently operate DKIST and NISP and continue to advance the frontiers of solar physics. This new structure will have its headquarters collocated with the University of Colorado, Boulder (CU) and will integrate the NSO staff currently divided between sites at Sunspot, New Mexico and in Tucson, Arizona.
- Developing the DKIST operations team in Maui.
- Development of the adaptive optics (AO), multi-conjugate AO (MCAO), and infrared (IR) technology needed for the DKIST.
- Operating the Dunn Solar Telescope (DST) until two years prior to the commencement of the DKIST regular operations and maintaining its competitiveness through AO, MCAO and state-of-the-art instrumentation.
- Establishing funding partners for the operation of NISP.
- Developing partnerships to establish and, if funding allows, lead a multi-station future synoptic network.
- Helping a consortium of partners, such as the New Mexico State University and the Southern Rockies Education Centers, with plans for pursuing their interest in assuming operations of Sacramento Peak, including the Dunn Solar Telescope.
- Helping the scientific consortium that plans to assume operation of the McMath-Pierce Solar Telescope (McMP) in a timely fashion to meet the NSF mandate to divest, or to close the facility if the consortium fails to provide increasing levels of support for operating the telescope at a rate of 25% of the total cost per year.
- Increasing diversity of the solar workforce.

Some of the programmatic highlights of the NSO program in FY 2015 include:

• Continuation of DKIST construction on Haleakalā.

- Start implementing the plans for relocating NSO Headquarters to CU-Boulder as detailed in NSO's Transition Plan.
- Start forming the core teams for DKIST operations in Boulder and Maui, including hiring key personnel for the DKIST Data Center.
- Upgrade SOLIS to produce vector chromoshperic magnetograms and install the Full-Disk Patrol (FDP) tunable filter. Select a new site for SOLIS.
- Collaborate with the University of Colorado on remodeling the 3rd floor of the Space Science Center (SPSC) building at CU's East Campus for NSO staff to begin occupancy. Sign the MOU between AURA and CU to consolidate the timeline for new faculty and fellowship positions.

A few of the major actions to advance solar physics that NSO will undertake in FY 2015 include:

- Continuing the construction of DKIST through the NSF Major Research Equipment Facilities Construction (MREFC) program.
- Proactively integrate NSO in the CU-led Collaborative Graduate Education Program (CGEP).
- Continue to seek new and stable funding lines for the NSO Integrated Synoptic Program (NISP) (e.g., OMB/OSTP white paper).
- Visit Universities throughout the US to publicize the DKIST project status and pursue potential partnerships.
- Promote international participation in DKIST.
- Enhance NSO's Outreach Program by hiring Education and Public Outreach (EPO) staff to publicize NSO's solar science broadly to the public.

FY 2015 is the first of a new 10-year-long Cooperative Agreement (CA) between the NSF and AURA to manage the National Solar Observatory. This new CA includes the resources needed for developing the operations teams and facilities of the Daniel K. Inouye Solar Telescope (formerly known as the Advanced Technology Solar Telescope) being built in Hawai'i. A \$5M funding wedge that begins in FY15 and increases to \$17M in FY19 is expected for operating this cutting-edge facility. The Observatory budget in FY15 is composed of the \$8M received in FY14 for regular operations and the funding wedge for DKIST operations, totaling \$13M. This budget is distributed among the four NSO sites: Sunspot, Tucson, Boulder and Maui.

In Sunspot, we continue to operate the Dunn Solar Telescope, which is still in high demand by the community. The DST is also being used by DKIST instrument teams for testing technologies (from fiber optics integral field units to narrow band prefilters). The telescope is occasionally operated in Service Mode as a test toward understanding some of the challenges we may face by operating DKIST in a similar way. FY 2015 will see regular operations of the facility and a consolidation of a plan to ramp down DST access by the end of FY 2017. NSO is collaborating with potential partners to ensure the continuation of activities in Sunspot and operation of the DST. We are also in contact with the institutions operating the largest high-spatial resolution

solar facilities currently available (Big Bear Solar Observatory (BBSO) in California and the GREGOR on Tenerife in Spain) to negotiate possible venues of collaboration during the gap period between DST divestiture and DKIST operations; this period is expected to be no larger than two years.

In Tucson, the NISP team continues to operate and distribute data from the GONG and SOLIS facilities. SOLIS has been relocated to an engineering site, where major upgrades of the suite of synoptic instruments are being made before moving the facility to a final site where it can enhanced its role as the DKIST context imager—a recommendation included in the NSF/AST Portfolio Review. Continued interest in the GONG network by NSO stakeholders involved in Space Weather indicates the possibility of consolidating funding lines that can maintain operations in their present form. NSO will collaborate with these stakeholders to understand their needs and define operation scenarios that can be adjusted to the decreasing funding profile the program faces. The Kitt Peak-based McMath-Pierce Solar Telescope continues to provide unparalleled opportunities for solar observations in the range beyond 2 microns.

The FY 2015 budget ramps up the development of the facilities and teams in Maui for telescope operations and in Boulder for data analysis and distribution. In past years, support for these efforts were from NSO's base funding. The FY15 budget also includes funding for the lease of NSO's new Headquarters in Boulder. Availability of the new HQ space at CU-Boulder in 2015 has sparked the implementation of the NSO staffing plan as developed by top-level managers of the Observatory during the past year. Other major initiatives expected in FY 2015 are largely related to the development of the DKIST Data Center and the relocation of the NISP Digital Library (DL) and Virtual Solar Observatory (VSO); the latter includes relocation of hardware and NISP personnel. The first Maui-based DKIST operations staff will be hired in FY 2015.

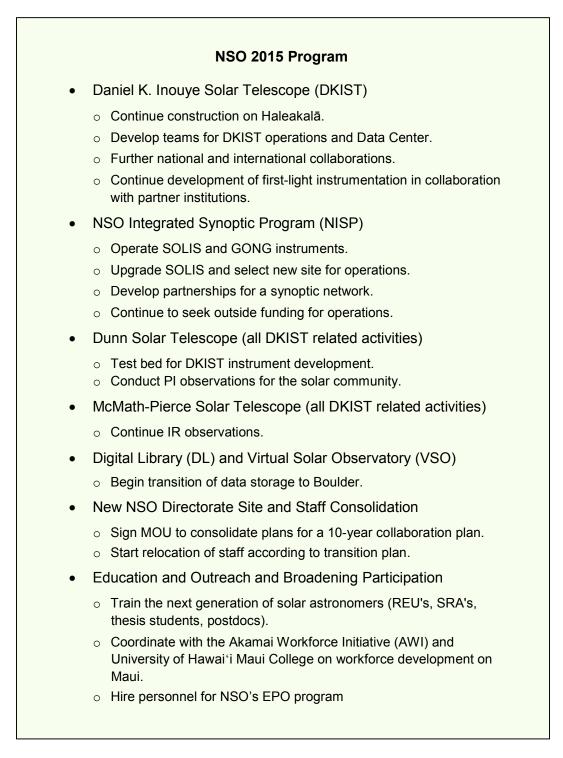


Figure 1. Planned and ongoing programs and projects at NSO.

2 FY 2014 SCIENTIFIC RESEARCH & DEVELOPMENT HIGHLIGHTS

2.1 A Multi-Instrument Analysis of Sunspot Umbrae

W. Livingston (NSO) and colleagues M. Penn (NSO) and L. Svalgaard (Stanford U.) have studied the magnetic properties of sunspot umbrae over the last 17 years using data from the Baboquivari instrument (BABO) at the McMath-Pierce Solar Telescope Facility (McMP), the Michelson Doppler Imager (MDI) instrument onboard the Solar and Heliospheric Observatory (SOHO) and the Helioseismic and Magnetic Imager (HMI) instrument onboard the Solar Dynamic Observatory (SDO). Automated sunspot detection algorithms were applied to the space-based data and were used in conjunction with Livingston's manual sunspot detections to allow a comparative analysis between the two catalogs containing 26921 and 2700 sunspot umbra detections respectively.

The well established relationship between magnetic field in sunspot umbrae and umbral intensity was tested and was shown to hold for each of the datasets, with the umbral magnetic field increasing as the umbral intensity decreased. The HMI data showed a far better correlation due to increased spatial resolution and lower noise level.

An analysis of the temporal evolution of sunspot umbral fields was a primary focus of this work and showed a small decrease in the mean umbral field strength over the 17 years studied, however the decrease was not as large as previously reported in the literature by Livingston, Penn and Svalgaard (*ApJ* **757**, 2012), giving a

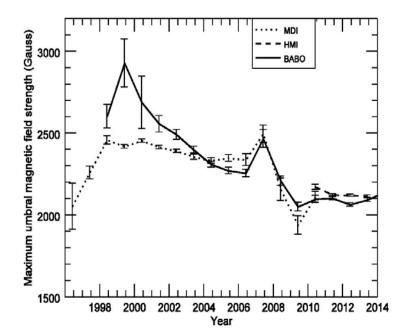


Figure 2.1-1. Annual average magnetic field strength in the darkest part of sunspot umbrae for the MDI, HMI and BABO datasets. The space and ground based data agree well after 2004-2005 but not before that time.

result of 300 Gauss in the present study compared to 800 Gauss. Taking a closer look at the data, we found that there is better agreement between the datasets after the beginning of 2005 than before that time. A sampling of individual sunspots over time was used to test for possible changes in one of the instruments used but no substantial difference was found. An explanation was discovered concerning the number of observations in the BABO dataset. As the umbral detection rate is expected to correlate with the sunspot number, and this is only the case with the BABO data after sometime in the 2003-2005 period, we conclude that the BABO data before that time are not representative of the full sunspot population and so care must be taken when using the BABO data to look at long-term trends. Since 2005, the BABO data

agree with the space-based MDI and HMI data and provides a good sampling of the sunspot population.

Finally, a comparison was made for sunspot intensities over time and the MDI and HMI data revealed that, on average, umbral intensities of sunspots did not vary over time at the wavelengths used by the instruments. This seems to disagree with the statements that umbral magnetic fields change over time and there is a correlation between umbral magnetic field and intensity. We resolved this by showing that the range of magnetic fields measured for umbrae of a given intensity was larger than the 300 Gauss change seen over the length of this study.

2.2 Solar Irradiance Monitor Measurements Analyzed Using MHD Simulations

Solar irradiance varies with magnetic activity, over periods of days to centuries and even on longer time scales. The magnitude of irradiance variations strongly depends on wavelength. Recent measurements obtained with the Spectral Irradiance Monitor (SIM) radiometers onboard the Solar Radiation and Climate Experiment (SORCE) show an irradiance signal at visible and IR spectral bands out of phase with the solar cycle. These results have been largely debated, since the majority of reconstruction models employed so far to successfully reconstruct the Total Solar Irradiance (the irradiance integrated over the whole spectrum) and the irradiance in the UV, do not reproduce such a signal. In particular, such results would indicate a negative contribution of solar faculae at those wavelengths, whereas faculae have always been thought to contribute positively to the irradiance.

Several irradiance reconstruction techniques employ static onedimensional atmosphere models to reproduce the variations measured by radiometers. We instead analyzed the emergent radiation at SIM wavelength bands through a set of 40 magnetohydrodynamic (MHD) snapshots of the solar photosphere obtained with the Stagger code and characterized by different amounts of average vertical magnetic field (namely, 0 - hydrodynamic (HD) in the following, 50, 100 and 200 G). The HD and the 50 gauss (G) snapshots represent quiet regions, while the 100 G and the 200 G represent facular regions. For the

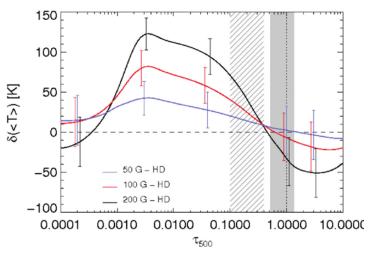


Figure 2.2-1. Difference between the average temperature stratifications of the magnetohydrodynamic (MHD) snapshots and the hydrodynamic (HD) snapshot.

purpose of this study, the main characteristic of the snapshots is that the temperature gradient becomes shallower with the increase of the magnetic field, as illustrated in Figure 2.2-1. The reasons for these temperature changes are explained in detail by Criscuoli 2013, *Astrophysical Journal*, 778, 27. A similar temperature-gradient variation of facular regions has been invoked in the past to interpret SIM measurements. The full and dashed gray areas represent

approximately the formation heights of the four visible and infrared wavelength bands monitored by SIM (namely, 400 - 691 nm, 691 - 972 nm, 972 - 1630 nm, and 1630 - 2423 nm) along the vertical and the $\mu = 0.2$ (μ is the cosine of the heliocentric angle) lines of sight, respectively.

The average contrast (defined as the ratio between the average emergent intensities of the MHD and the HD snapshots) for the different snapshots and for various lines of sight is illustrated in Figure 2.2-2. The plots show that, especially for vertical lines of sight, and for wavelengths that form deeper in the atmosphere, where the temperature decreases with the increase of the average magnetic flux (see Fig. 2.2-1), the contrast is negative. For shallower lines of sight the formation-height shift toward higher layers of the atmosphere, where the temperature increases with the increase of the average magnetic flux, and therefore the contrast becomes positive at all wavelengths. These results suggest that the contribution of faculae to irradiance can be negative if such features are mostly located toward disk center. To verify this result, we computed the radiative flux at the four SIM bands supposing that magnetic features are mostly located over the activity belt (that is a region extending ± 30 degrees around the Equator); this is a good approximation when considering several solar rotations. The ratio between the radiative flux of the MHD and HD snapshots for the various bands is shown in which shows that, at least for two wavelengths bands (namely 400 - 691 nm and 1630 - 2423 nm) which are those that form deeper in the atmosphere, the radiative flux decreases with the increase of the average magnetic field. Moreover, if we take as a reference the 50 G snapshots, the contribution at those wavelength bands is always negative.

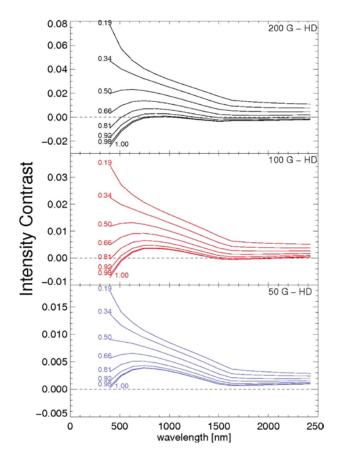


Figure 2.2-2. Average intensity contrast for different wavelengths and lines of sight for the various MHD snapshots employed in this study.

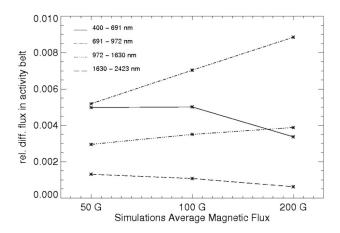


Figure 2.2-3. Relative difference between the radiative flux integrated over the four SIM bands obtained with the MHD and the HD snapshots, supposing magnetic features to be evenly distributed over the activity belt (a region extending from + to - 30 degrees around the Equator).

The results obtained by our analysis confirm that the contribution of magnetic features (to irradiance) strongly depends on their location on the solar disk. Since magnetic regions emerge at higher latitudes (where their contribution to irradiance is higher) at the beginning of the cycle and then at lower latitudes (where their contribution decreases), we conclude that it is possible to measure irradiance variations out of phase with the magnetic activity. In particular, if we take as a reference the 50 G snapshots (which previous investigations have shown to better represent the quiet Sun with respect to HD snapshots), then the contribution of facular regions to irradiance integrated over several solar rotations is always negative at least at two of the SIM visible and IR wavelength bands.

2.3 McMath-Pierce Offers New Spectropolarimetry at 4137 nm

The new cooled-grating spectropolarimeter (CYRA) is nearing completion. The instrument will make dual-beam spectro-polarimetric observations from 1000 to 5000 nm at the New Solar Telescope (NST) operated by the New Jersey Institute of Technology (NJIT) at Big Bear Solar Observatory (BBSO). As one of the initial science goals for the instrument, spectro-polarimetric measurements of several spectral lines near 4137 nm will be made to explore active region and quiet Sun magnetic fields with high spectral sensitivity.

The spectral sensitivity of any line is the ratio of the Zeeman splitting to the Doppler broadening, and and is proportional product to the of wavelength times the effective Landé gfactor. This product is equal to 1575 for the well-known Fe I lines at both 525 and 630 nm. For the 1565 nm Fe I ("infrared line") the product is 4695, and so this line has more than three times the magnetic sensitivity of the visible lines. The most sensitive line currently identified in the solar spectrum is the Mg I line at 12318 nm, which has a geff=1 and thus a magnetic sensitivity of 12318.

To test the CYRA polarization optics, the NSO Array Camera (NAC) at the McMath-Pierce facility was used in

Fe I 4139		telluric	Fe I Fe I 4136 4137
ОН	ОН		он он
SiO		SiO SiO	

Figure 2.3-1. Stokes I spectrum with the slit crossing a sunspot taken with the CYRA polarization optics and the NAC camera a the McMP. Two obvious Fe I lines are seen along with a weaker FeI line at 4137 nm. Several molecular lines are seen in the sunspot umbra.

conjunction with the Main spectrograph. The warm optics of the spectrograph produced a high background which is not expected for the cooled CYRA instrument, but several test runs have been done and full Stokes spectra have been observed in the 4135-4139 nm spectral window. Below the Stokes I (Fig. 2.3-1) and Stokes V (Fig. 2.3-2) average of several spectra in a sunspot are shown. The spectra show a strong telluric absorption line at 4138 nm and two Fe I lines at

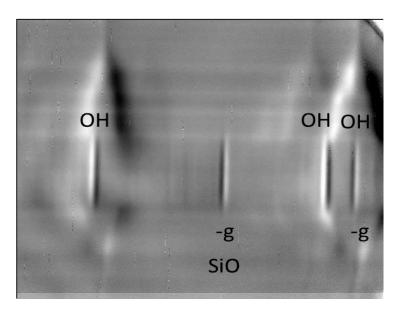


Figure 2.3-2. Stokes V spectrum of the same region shown in Figure 2.3-1. Systematic gain correction errors are seen, but the Zeeman splitting profiles of several spectral lines are visible above the noise level.

4136.49 and 4139.23 nm. A weak spectral line is also seen, and is thought to be the Fe I absorption at 4137.01 nm. The spectral lines show strong splitting in the sunspot penumbra, but are highly temperature sensitive and are not detected in the sunspot umbra. Signals measured in the quiet Sun regions with the Fe lines in these test observations show mostly seeing induced cross-talk signatures since a slowchopping single-beam optical setup was used. In the sunspot umbra, several molecular lines of OH and SiO are observed, and some of these lines show Stokes V profiles indicating a negative value for g_{eff}.

Using the spectral line lists of Kurucz, we can compute g_{eff} values of 1.62, 2.81 and 1.32 respectively for the 4136, 4137 and 4139 nm lines, resulting in magnetic sensitivity values of 6701, 11624 and 5464. If instead we use L-S coupling the values for g_{eff} are 1.7, 3.0 and 1.0, resulting in magnetic sensitivity values of 7032, 12411 and 4139 respectively. In both cases, the 4137 nm line proves to be extremely sensitive to magnetic fields on the Sun, and the L-S coupling value suggests that it would be the most sensitive spectral line known so far. Examining the Stokes V profiles of this line reveals a complicated splitting, however, and more work is needed to understand its Zeeman pattern and how to use it for magnetic measurements on the Sun. Continued observations of this line are planned for both the New Solar Telescope and McMath-Pierce Solar Telescope.

2.4 A New Solar Fluorine Abundance

The origin and evolution of fluorine in the galaxy is still very much under debate. This evolution is worth considering because fluorine creation and destruction in stellar interiors is very sensitive to the physical conditions, implying that observations of fluorine abundances can provide constraints on stellar evolution models. State-of-the-art stellar astrophysics predicts that there are three main sources of fluorine production, neutrino spallation of ²⁰Ne to ¹⁹F in type II supernovae, nucleosynthesis in the He rich intershell of thermally pulsing AGB stars, and perhaps nucleosynthesis in the He burning cores of Wolf-Rayet stars. It is still unclear which of these mechanisms is the main contributor. It is clear, however, that there is a need for a solid determination of the solar fluorine, as this is the standard against which all determinations are measured.

The solar abundance value that has been used for decades until now, $A_F = 4.56$, was determined by Hall and Noyes (1969) based on dated theoretical values of the energy levels and oscillator strengths of the HF molecule, which is the only fluoride compound that produces observable lines in the visible part of the solar spectrum. Since fluorine has an outer electron shell that is full but for one electron, its outer electrons are tightly bound to the atom and require an energy in excess of 12 eV to be excited. Such excitations are very rare in the solar photosphere and chromosphere, explaining the

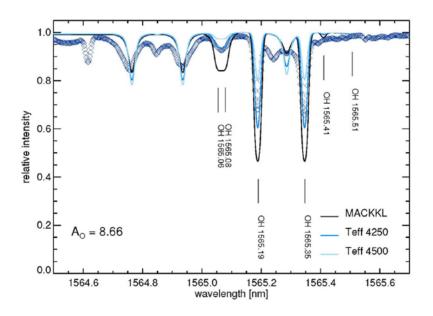


Figure 2.4-1. Effective temperature of 4250 K comes closest to reproducing the observed OH lines, in particular the weaker ones, which form at the same heights as the HF line that Maiorca and colleagues wanted to reproduce.

lack of observable fluorine lines in the solar spectrum, as the higher energy levels, connected by visible lines, are never sufficiently populated. HF, however, has a low dissociation energy of 5.87 eV, causing it to be only significantly present in relatively cool sunspot umbrae. Therefore, the solar fluorine abundance has to be determined by fitting HF line profiles to those observed in umbral spectra, as indeed was done by Hall and Noyes.

Recently, new values of the parameters for HF rotation–vibration lines became available via the HITRAN data base. These values were significantly different from the old ones, prompting an effort to adjust the solar fluorine abundance. E. Maiorca (INAF, Arcetri Observatory) and colleagues H. Uitenbroek (NSO), S. Uttenthaler (U. Vienna), S. Randich (INAF, Arcetri), M. Busso (INFN, Perugia) and L. Magrini (INAF, Arcetri) (*ApJ* **788**, 2014) have undertaken such an effort, comparing with the solar umbral atlas from Hinkle and Wallace, and using radiative equilibrium models of Kurucz with different effective temperatures, as well as the medium-cycle sunspot model of Maltby et al. for modeling.

To determine the proper effective temperature corresponding to the umbral atlas, Maiorca et al. first fitted lines of the OH molecule, which are strongly temperature dependent, at 1.5 micron. The results are shown in Figure 2.4-1. Clearly the atmosphere with an effective temperature of 4250 K comes closest to reproducing the observed OH lines, in particular the weaker ones, which form at the same heights as the HF line that Maiorca and colleagues wished to reproduce. Next they varied the fluorine abundance in the T_{eff} = 4250 K model until they best fit the 8 HF lines in the umbral atlas. The results for one of the lines, the R 9 line, is shown in Figure 2.4-2, where the atlas is plotted in light-blue diamonds and the model spectrum in the solid black curve. The new solar abundance for the best fit is $A_F = 3.80$, significantly lower than the old value determined by Hall and Noyes.

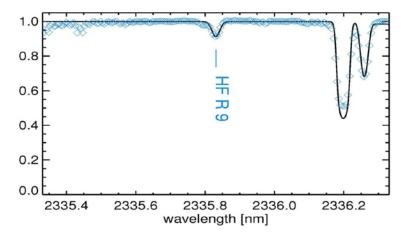


Figure 2.4-2. Results of the R 9 line, where the atlas is plotted in light-blue diamonds and the model spectrum in the solid-black curve.

The new value of the fluorine abundance is significantly smaller than that determined by Hall and Noyes, and is mostly a result of new the the experimental oscillator strengths for the HF lines. It is also smaller than the value determined in chondrite meteorites, but this value itself is rather old, and the most recent publication presenting it states that "It seems that the last word on fluorine in meteorites has not said." been With vet an independent measurement of

fluorine abundance in open cluster stars with very similar metallicities, Maiorca et al. find very good agreement with their new solar value, giving them confidence in this value.

2.5 Active Regions with Superpenumbral Whirls and Their Subsurface Kinetic Helicity

Sunspots come in many sizes and shapes and are locations of strong magnetic fields which extend from below the solar surface through the solar atmosphere into the interplanetary medium. They are also the locations of eruptive phenomena, such as flares, which release a tremendous amount of energy and can disrupt technology on Earth. The resulting space weather creates not only the beautiful polar lights but also affects the accuracy of navigation systems (GPS) and threatens the safety of astronauts. Since twisted magnetic fields in large complex sunspots are the likely origin of energy for solar flares, it is of interest to understand the origin of this twist to im- prove spaceweather forecasting.

Some spots are deceptively simple; such as the sunspot in AR 11092, observed in August 2010, which was nearly round and not particularly large. It was thus surprising for NSO scientists R. Komm, S. Gosain, and A. Pevtsov (*Solar Phys.* **289**, 2014) to see that its magnetic field was twisted in such a way as to resemble a pinwheel or hurricane that is rotating counter-clockwise (see Figure 2.5-1). High in the solar atmosphere, sunspot magnetic fields can be detected by a mixture of darker structures (that are usually twisted in all directions). A twist in the same direction happens only on rare occasions as in the case of the sunspot in AR 11092. While the orientation of the twist is clearly visible high in the atmosphere, what is the orientation of the twist at lower heights and below the solar surface? One might expect it to be the same. But if not, it would be a clue towards solving the mystery of the causes of solar activity.

Measurements of the strength of the magnetic field along different directions in the lower solar atmosphere are now being made with the vector spectromagnetograph (VSM) instrument of the Synoptic Optical Long-term Investigations of the Sun (SOLIS) facility of NSO. Below the surface, the magnetic field can be estimated by using the motions of the solar material as a proxy. Currently, the only way to measure anything below the solar surface is with helioseismology, which studies changes in sound waves as they travel through the solar interior just as seismology is used in geophysics to study the Earth's interior. These observations are obtained with the Global Oscillation Network Group (GONG) facility of NSO.

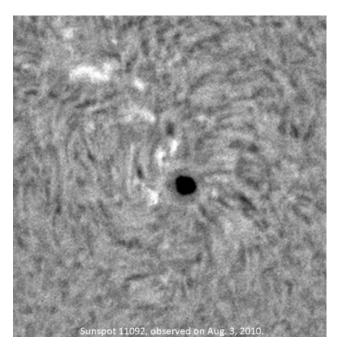


Figure 2.5-1. Sunspot 11092, observed on August 3, 2010.

Using data from SOLIS and GONG, Komm and colleagues found that the twisting in the lower solar atmosphere is in the same direction for the sunspot in AR 11092 as seen higher up. They found that below the surface, however, the twisting is in the opposite direction. They investigated another sunspot with a clockwise whirl, and found the same result. As a control experiment, Komm and colleagues analyzed six sunspots without a persistent whirl pattern. The orientation of the twist of the magnetic field at low heights turned out to be the same as that of the flows below the solar surface for four of the six regions. This suggests that opposite direction of twist above and below the solar surface is indeed a characteristic of active regions with whirls. But, could this be a coincidence due to the small sample size? NSO scientists plan to analyze many more active regions to find out. If the relationship turns out to be true, then there must be a thin region immediately below whirling sunspots over which the twist changes rapidly. This could result in an unstable zone that could trigger flares.

2.6 Quantum Well Infrared Photodetector (QWIP) Observations from the McMath-Pierce Solar Telescope

The first solar observations with a quantum well infrared photodetector (QWIP) camera array were done at the NSO 1.6 m McMath-Pierce telescope during the summer of 2013. An array with neighboring pixels with different wavelength sensitivities from NASA Goddard Space Flight Center was used to image the continuum emission from the solar surface at 5 and 10 microns simultaneously, providing views of sunspots and active region plage at these seldom observed wavelengths. The figure shows two views of active region NOAA 11765 from June 8, 2013. At these wavelengths the diffraction limit of the telescope is about 0.6 and 1.2 arcseconds respectively. In each image sunspot and plage, structure is visible, and the plage contrast is enhanced at the longer wavelength due to the increase in the height of formation of the solar

continuum at this wavelength (roughly z = 160 km). Solar granulation can be seen in the best images in both wavelength channels, and a movie sequence shows that *p*-mode oscillations are also present in the quiet Sun regions. At 10 microns the center of the sunspot umbra is measured at about 80% of the continuum intensity, and combined with reduced instrumental and atmospheric stray-light, observations at this wavelength will be well-suited for probing *p*mode interactions with magnetic activity. Scans across the solar limb showed a large difference in the solar limb darkening at these two wavelengths, and test images of the entire solar disk were also taken using the 2.1 m heliostat. More solar observations with this array are planned for 2014.

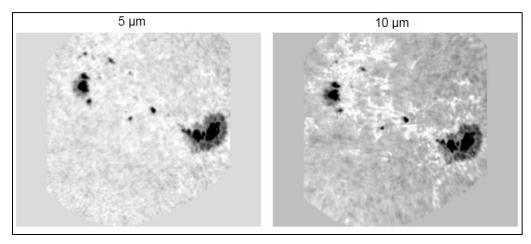


Figure 2.6-1. Infrared continuum images of NOAA 11765 taken with the NASA/GSFC QWIP array at the McMath-Pierce facility. Properties of the camera allow these images to be taken simultaneously. Since the continuum is formed at different heights at these two wavelengths, the camera enables unique studies of dynamic events in the solar photosphere.

3 SCIENTIFIC AND KEY MANAGEMENT STAFF

The NSO staff provides support to users including observational support, developing and supporting state-of-the-art instrumentation to ensure that users obtain the best data, and maintaining data archives and the means to accessing the data. Members of the scientific staff are defining how DKIST will be operated and how NSO will handle the data. In addition, both scientific and engineering staff serve as mentors for undergraduate and graduate students and postdoctoral fellows. They also organize community workshops on critical areas of solar research and planning. Staff science and instrument development allows NSO to stay at the forefront of solar physics and play a crucial role in fulfilling user support.

The current NSO scientific and management staff, as well as affiliated scientific staff, are listed below with their primary areas of expertise and key observatory responsibilities.

Scientific Staff

Christian Beck	DST visitor and instrument support; solar magnetic fields and convection; DKIST operations development.
Luca Bertello	NISP/SOLIS Data Scientist; solar vector magnetic fields; helioseismology.
Serena Criscuoli	DST visitor and instrument support; solar magnetic fields and convection; DKIST operations development.
David F. Elmore	DKIST Instrument Scientist; ground-based spectrograph and filter-based polarimeter development.
Mark S. Giampapa	Current NSO Deputy Director; Ch., NSO/KP Telescope Allocation Committee; stellar dynamos and magnetic activity; asteroseismology; astrobiology.
Sanjay Gosain	Spectropolarimetry; solar magnetic fields; instrumentation.
Brian J. Harker	Stokes spectropolarimetry and inversion techniques; automated tracking and classification of sunspot and active-region structure; parallel processing computational techniques for data reduction.
John W. Harvey	NISP; solar magnetic and velocity fields; helioseismology; instrumentation.
Frank Hill	NSO Associate Director for NISP; solar oscillations; data management.
Stephen L. Keil	Solar variability; convection.
John W. Leibacher	NISP; helioseismology; atmospheric dynamics; NSO Diversity Advocate
Jose Marino	DKIST wavefront correction; image restoration.
Valentín Martínez Pillet	NSO Director; solar activity; magnetic field measurements; spectroscopy; polarimetry; astronomical instrumentation.
Matthew J. Penn	Solar atmosphere; solar oscillations; polarimetry; near-IR instrumentation; DKIST near-IR; McMath-Pierce Telescope Scientist.

Gordon J. D. Petrie	NISP; solar magnetism; helioseismology.
Alexei A. Pevtsov	NISP/SOLIS Atmosphere Program Scientist; solar activity; Ch., Scientific Personnel Committee; coronal mass ejections; solar magnetic helicity, Sun- as-a-star.
Kevin P. Reardon	Data Center Scientist; high-resolution solar data acquisition and analysis; DKIST data handling, storage and processing.
Thomas R. Rimmele	NSO Associate Director for DKIST; DKIST PI and Project Director; solar fine structure and fields; adaptive optics; instrumentation.
Alexandra Tritschler	DKIST operations development; solar fine structure; magnetism; Stokes polarimetry.
Han Uitenbroek	DST Program Scientist; atmospheric structure and dynamics; radiative trans-fer modeling of the solar atmosphere; DKIST Visible Broadband Imager.
Friedrich Wöger	DKIST Data Handling Scientist; DKIST Visible Broadband Imager PI; high- resolution convection; solar fine structure; magnetic fields.

Key Management Staff

Steven Berukoff	DKIST Data Center Project Manager.
Craig Gullixson	DST Technical and Project Manager.
Rex G. Hunter	NSO budget management; DKIST business support; Support Facilities and Business Manager.
Joseph P. McMullin	DKIST Project Manager.
Priscilla Piano	Administrative Manager: Director's office and Tucson site support; NSO grants and NSO budget management.
Kim V. Streander	NISP Program Manager; NSO/KP Technical Program & Telescope Manager

Postdoctoral Fellows

Dirk Schmidt	DKIST Postdoctoral Fellow; multi-conjugate adaptive optics.
Fraser T. Watson	Sunspot identification and evolution.

Thesis Students

Teresa Monsue	(Fisk/Vanderbilt U.)	Solar flares.
Matthew Richardson	(Fisk University)	Helioseismology.
Courtney Peck	University of Colorado	Solar irradiance variation

Grant-Supported Scientific Staff

Olga Burtseva Time-distance analysis; global helioseismology; leakage matrix.	
Kiran Jain	NISP Interior Program Scientist; helioseismology; solar cycle variations; ring-diagram analysis; sub-surface flows.
Shukur Kholikov	Helioseismology; data analysis techniques; time-distance methods.
Rudolf W. Komm	Helioseismology; dynamics of the convection zone.
Sushanta C. Tripathy	Helioseismology; solar activity.

Tab	Table 3.1 NSO Scientific Staff Estimated Percent FTE by Activity (FY 2014)							
Name	Adm/Mgt ¹	Research ²	EPO ³	Project Support	User Support	Internal Comm.	External Comm.	TOTAL
Beck, C.		51.2	3.8	19.4	25.6			100.0
Bertello, L.		51.0		29.0	20.0			100.0
**Burtseva, O. ^a		50.0						50.0
Criscuoli, S.		48.4	2.9	11.1	36.6	1.0		100.0
Elmore, D.F.		1.0	2.0	95.0		2.0		100.0
** ^b Fox, L.J.		66.0	2.0		32.0			100.0
Giampapa, M.S.	50.0	39.1	0.3	1.0	0.2	0.3	9.1	100.0
Gosain, S.		32.8		59.2	8.0			100.0
Harker, B.J.		38.5	0.5	41.0	20.0			100.0
Harvey, J.W.		20.0		62.8	15.0		2.2	100.0
Hill, F.	62.0	4.6	1.0	26.3		2.4	3.7	100.0
**Jain, K.	10.0	31.2		58.3		0.5		100.0
Keil, S.L.	30.0	20.0	4.0	41.0		5.0		100.0
**Kholikov, S.S. ^a		33.0		10.0	7.0			50.0
**Komm, R.W.		94.0		5.0			1.0	100.0
Leibacher, J.W.		10.0	2.0	66.6		8.1	13.3	100.0
**Marino, J.		10.0		90.0				100.0
Martinez Pillet, V.	100.0							100.0
Penn, M.J.		34.5	13.5	42.8	4.6	0.5	4.1	100.0
Petrie, G.J.D.		62.0	8.0	30.0				100.0
Pevtsov, A.A.	10.0	20.3	2.6	52.4	5.9	1.0	7.8	100.0
Reardon, K.P.		18.1		55.8	26.1			100.0
Rimmele, T.R.	75.8	1.0	1.0	22.2				100.0
Schmidt, D.		10.0		90.0				100.0
**Tripathy, S.C.		74.0		25.0		1.0		100.0
Tritschler, A.	3.7	6.1	0.5	89.7	2.3	1.3		100.0
Uitenbroek, H.		39.1	0.5	17.7	25.5	11.5	5.7	100.0
Watson, F.		20.0	1.0	38.2	40.8			100.0
Woeger, F.	41.0	6.0	8.0	45.0				100.0

**Grant supported staff. ^a50% FTE ^bCompleted employment Aug 2014 ¹Administrative and/or Management Tasks.

²Research, including participation in scientific conferences. ³Educational and Public Outreach.

4 SUPPORT TO THE SOLAR COMMUNITY

Fulfilling NSO's mission of providing opportunities to the scientific community and training the next generation of solar researchers for forefront observations of the Sun require that first-class ground-based solar facilities remain available on a continuous basis. Thus NSO developed Long-Range Plans with the flexibility to transition from current facility operations to the period when new facilities are in place without seriously impacting the US solar user community. Through advancements in instrumentation and the implementation of adaptive optics at its focal planes, NSO has maintained its telescopes at the cutting edge of solar physics. They play a key role in the support of US and international solar research and research-based training.

As mandated in the NSF solicitation for the renewal of the NSO's Cooperative Agreement, after 2017 the major telescope facilities managed by NSO will be divested. With 2019 as the expected date for DKIST first light, we face a two-year gap during which NSO will have no observing time to offer to the community for high-spatial resolution investigations. The synoptic program is expected to be fully operational during this gap, including an upgraded SOLIS instrument suite relocated to a new site. A number of options are being discussed to fill this gap. One option is to gain access to observing time at the two most competitive solar telescopes that have recently started operations: the New Solar Telescope (NST), a 1.6-m aperture telescope) at Big Bear (California) and the German Gregor telescope (1.5-m aperture) on the Canary Islands (Spain). The NST is an off-axis telescope with coronal capabilities and cryogenically cooled infrared instruments that resemble some of the future DKIST capabilities. The Gregor telescope was built by the Kiepenheuer Institute for Solar Physics (KIS; Freiburg, Germany) and NSO has started conversations with KIS about establishing a collaboration that would allow NSO to offer Gregor time to the US community. Another option is to internally develop a Web-based search tool for efficient data mining and retrieval of existing high-spatial resolution observations, in particular those made at the DST in Service Mode. Discussion at a recent meeting of the NSO Users' Committee has started to define how to best fill this gap according to the interests and needs of our community, keeping in mind the limited available resources.

4.1 Dunn Solar Telescope

The 76-cm Richard B. Dunn Solar Telescope (DST), located on Sacramento Peak, is a diffractionlimited solar telescope with strong user demand and excellent scientific output. The DST has two identical AO systems—well matched to seeing conditions—that feed two different instrument ports. These ports accommodate a variety of diffraction-limited, facility-class instrumentation, including the Diffraction-Limited Spectro-Polarimeter (DLSP), the Spectro-Polarimeter for Infrared and Optical Regions (SPINOR), the Interferometric BIdimensional Spectrometer (IBIS), the Facility Infrared Spectrograph (FIRS), the Rapid Oscillations of the Solar Atmosphere (ROSA). This has made the DST on of the most powerful facilities available in terms of post-focus instrumentation.

In addition to supporting the solar community and the science discussed in Section 2, the DST supports observations that will drive DKIST high-resolution requirements at visible and near-infrared wavelengths, and refine DKIST science goals. The DST also supports the development

of future technologies such as multi-conjugate AO (MCAO), and experimental wavefront sensing on off-limb targets in H-alpha. The first successful on-sky MCAO experiment was performed at the DST in 2009 and further efforts are ongoing. A prototype for off-limb AO in H-alpha was completed in 2014.

The DST supports the US and international high-resolution and polarimetry communities and is often used in collaboration with space missions to develop global pictures of magnetic field structure and evolution. While competing European and privately funded US telescopes have emerged, they have not supplanted the need for the DST. Many Europeans still compete for time on the DST and provide instruments, such as IBIS (Italy) and ROSA (Northern Ireland, UK), that are available as facility instruments to all users. The DST will continue to play the major role in supporting US high-resolution spectro-polarimetry and the development of instruments needed for progress in this important field.

The NSO instrumentation program is focused on the development of technologies that will be central to the DKIST and a strong program of understanding solar magnetic variability. The primary areas of instrumental initiatives at NSO are high-resolution vector polarimetry in the visible and near-IR. Many of the instruments at the DST can be considered prototypes for DKIST first-light instruments. For example, FIRS (Facility Infrared Spectro-polarimeter) and the new fiber-optic spectrograph SPIES (Spectro-Polarimetric Imager for the Energetic Sun) implement and verify state-of-the-art technologies that will be used for the DL-NIRSP (Diffraction-Limited Near-Infrared Spectro-polarimeter) of DKIST. SPINOR is a precursor to DKIST's ViSP (Visible Spectro-polarimeter) and ROSA implements and tests concepts that drive the design of the DKIST VBI (Visible Broadband Imager) and camera systems. IBIS, a partner instrument provided to the DST by INAF in Italy is operated by NSO with support from the Italian community. This collaboration does not only provide experience with the design, operations, data handling and processing of such a complex instrument but also teaches valuable lessons on making international partnerships work successfully and with mutual benefit. IBIS can be regarded as a prototype for the Visible Tunable Filter (VTF), which will be provided to DKIST by an international partner as well. Instrument development and scientific applications in these areas rely critically on strong collaborations with university and international partners.

DKIST operational concepts are tested at the DST with the DST Service-Mode Operations (SMO). Service mode is an operational mode in which the PI of the observing request does not travel to the telescope. Instead, observations are ranked, scheduled and performed by a team of telescope scientists at the DST. This mode of scheduling is more efficient, allows a flexible schedule that maximizes adaptation to solar target availability and atmospheric conditions, and wastes less time waiting for opportunities and changing instrumentation. It is expected that the DKIST will be run in Service Mode for a significant fraction of its operational time. Lessons that need to be learned include how to rank proposals, how to plan and react to target availability, how to disseminate the acquired data, and how to coordinate with solar space missions on a short time scale. Three SMO experiments have been conducted for one month each in January/February and October 2013, and October 2014. All three experiments saw high interest from the community, with 21 and 19 observing requests in the first two cycles, respectively, and 10 proposals for the third cycle that was especially targeted to the observation of solar flares.

4.1.1 DST Instrumentation

4.1.1.1 Diffraction-Limited Spectro-Polarimeter (DLSP)

The Diffraction-Limited Spectro-Polarimeter is fully integrated with one of the high-order AO systems (Port 2). In addition, a 1 Å K-line imaging device and a high-speed 2K x 2K G-band imager with speckle reconstruction capability as well as a broad-band slit-jaw imager have been integrated with the DLSP. A diffraction-limited resolution mode (0.09 arcsec/pixel, 60 arcsec FOV) and a medium-resolution mode (0.25 arcsec/pixel, 180 arcsec FOV) are available.

4.1.1.2 Facility Infrared Spectropolarimeter (FIRS)

This instrument is a collaborative project between the National Solar Observatory and the University of Hawai'i Institute for Astronomy (IfA) to provide a facility-class instrument for infrared spectro-polarimetry at the Dunn Solar Telescope. H. Lin (IfA) is the principal investigator of this NSF/MRI-funded project. FIRS takes advantage of the diffraction-limited resolution provided at infrared wavelengths by the AO system during a large fraction of the observing time. Many of the solar magnetic phenomena occur at spatial scales close to or beyond the diffraction limited resolution of the telescope. A unique feature of FIRS is the multiple-slit design, which allows high-cadence, large FOV scans (up to four times more efficient than SPINOR and DLSP), a vital feature for studying dynamic solar phenomena such as flares. The high-order Echelle grating allows for simultaneous multi-wavelength observations sensing different layers of the solar atmosphere, and thus enabling 3-D vector polarimetry. The two detectors are a 1K × 1K MgCdTe IR camera and a 2K × 2K camera with Kodak CCD for the visible arm, both synched to their own liquid crystal modulator. FIRS has been fully commissioned as a supported user instrument since 2009. It serves as a prototype for the Diffraction-Limited Near-IR Spectro Polarimeter (DL-NIRSP), a major DKIST first-light instrument.

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

SPINOR is a joint HAO/NSO instrument that replaced the advanced Stokes polarimeter (ASP) at the Dunn Solar Telescope with a much more capable system. The ASP has been the premier solar research spectro-polarimeter for previous instrument generations. SPINOR extends the wavelength of the former ASP from 450 nm to 1600 nm with new cameras and polarization optics, provides improved signal-to-noise and field-of-view, and replaces obsolete computer equipment. Software control of SPINOR into the DST camera control and data handling systems has been completed and the instrument is fully commissioned as a user instrument. FIRS, SPINOR and IBIS, are the primary instruments for joint observations with *Hinode*, SDO, and IRIS. They augment capabilities for research at the DST and extend the lifetime of state-of-the-art research spectro-polarimetry at the DST for another decade. SPINOR is also the forerunner of the Visible Spectro-Polarimeter (ViSP) that is being developed by HAO for the DKIST.

4.1.1.4 Interferometric BIdimensional Spectrometer (IBIS)

IBIS is an imaging spectrometer built by the solar group of the University of Florence in Arcetri, Italy, and the solar group at the University of Tor Vergata in Rome. IBIS delivers high spectral

resolution (25 mA in the visible, and 45 mA in the infrared), high throughput, and consequently high cadence. In collaboration with NSO and the High Altitude Observatory, IBIS was upgraded to a vector polarimeter. The wavelength range of IBIS extends from the visible to near-IR and allows spectroscopy and polarimetry of photospheric and chromospheric layers of the atmosphere. NSO has a Memorandum of Understanding with the University of Florence for continued operation and support of IBIS at the DST. Two new identical Andor 1K × 1K cameras have replaced the slower Princeton narrow-band and Dalsa wide-band cameras for improved data rates. IBIS has been integrated into the DST SAN for faster data storage. IBIS serves as prototypes for the Visible Tunable Filter (VTF) in the DKIST first-light instrument suite and provides experience in reducing the large data sets that instruments in the DKIST era will produce.

4.1.1.5 Rapid Oscillations of the Solar Atmosphere (ROSA)

ROSA is a fast camera system developed and built by Queen's University (QU) in Belfast, Northern Ireland. It consists of up to eight 1K x 1K Andor cameras, including one especially blue sensitive camera, an ultra-fast camera capable of sampling images at up to 60 Hz, and a computer system capable of storing data at these high rates. The computer system has an internal storage capacity of 20 Tb, enough for a few days of observations, even at the extremely high data rates the system is capable of. Typically, the cameras are fed through some of NSO's wide band filters in the blue, while the red light is fed to IBIS. The DST observers have been instructed on operating ROSA and are capable of running the instrument without assistance from QU. ROSA serves as an analogue for the DKIST's Visible Broad-band Imager (VBI).

4.1.2 Data Reduction Pipelines

Data reduction pipeline have been created for the most used facility instruments, IBIS, FIRS, and SPINOR and are available through the NSO Web site (*http://nsosp.nso.edu/dst-pipelines*). These software packages are supported by the local staff and allow users of the instruments to do the complicated reduction of spectro-polarimetric data at their own institution. Reduction of ROSA images is supported by Queen's University.

4.1.3 Replacement and Upgrades

4.1.3.1 Critical Hardware

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

4.1.3.2 Storage Area Network (SAN)

The high data volumes produced by existing and new instrumentation such as IBIS, SPINOR, FIRS, and ROSA, an instrument to measure Rapid Oscillations in the Solar Atmosphere, require an expansion in data storage and handling capabilities at the DST. The DST data handling system is currently 4 Tb for storage of daily observations, and 20 Tb for long-term (21 days or more) storage. A 10 Gbs network switch allows instruments to write to the SAN at the sustained high data rates required by high-spatial resolution, high-cadence spectro-polarimetry. Furthermore, the obsolete standard storage media, DLT tape, which was used to transfer data to users, has been completely replaced by removable hard drives with the eSATA or USB transfer protocols, for much higher throughput.

4.1.4 Current and Future Use of the DST

NSO users and staff will continue to vigorously pursue the opportunities presented by highresolution, diffraction-limited imaging at the DST, with a goal of testing models of magnetoconvection and solar magnetism, while refining DKIST science objectives and ensuring the growth of expertise needed to fully exploit DKIST capabilities. The advent of high-order AO has increased the demand for DST time and has given ground-based solar astronomy the excitement shared by space missions. Part of DST scheduling has been devoted to testing the main envisioned DKIST operation mode (often referred to as Service Mode), where PIs no longer visit the telescope, but rather submit proposals that are then put in a queue that is executed by NSO staff, based on scientific ranking, prevailing observing conditions, and solar conditions. These experiments have provided important information on the adjustments the new observing mode requires of the proposal submission process, the evaluation of proposals, scheduling, and change in staff roles, compared to the PI driven and fixed scheduling that now is standard at the DST. These experiments will be extensively evaluated and continued, as more needs to be learned.

4.1.5 Divestiture Planning

When DKIST is complete, the high-resolution capabilities of the DST will be surpassed and NSO will cease operations and either close the DST or, preferably, find a group or groups interested in exploiting the unique capabilities of the DST, including perhaps providing continued access to the NSO for both testing and educational purposes. Because NSO plans to ramp down its operation of the DST over several years, we will seek (a) group(s) willing to ramp up their presence in Sunspot over the same time frame. In order to develop a divestment plan, a series of workshops will be held, bringing together interested parties. Recently, NMSU has become interested in joining the efforts to turn the DST into a training facility for the younger generations of astronomers and engineers. The next step is to work out potential business plans and to coordinate with NSF on legal issues. This is an ongoing effort.

4.2 McMath-Pierce Solar Telescope

The McMath-Pierce Solar Telescope (McMP) facility is a set of three all-reflecting telescopes, with a main telescope with a primary diameter of 1.6 m, and the two auxiliary telescopes (East and West) with diameters of 91 cm and 88 cm. The McMP facility is the largest collection of solar telescopes in the world. The McMP provides large-aperture all-reflecting systems that can

observe across nearly two orders of magnitude, from 350 to 23000 nm; the telescopes are very configurable with light beams that can feed a number of large, laboratory-style optics stations for easy and flexible instrument setup. The McMP is unique since it is the only 1.6-m aperture solar telescope publicly available to any scientist, the only solar telescope with instrumentation that routinely observes in the infrared beyond 2500 nm, and the only solar facility in the world with instrumentation to observe the Sun at 12000 nm and beyond.

4.2.1 Diverse Observing Capabilities

As recognized by the decadal report (*New World New Horizons (Astro2010: Astronomy & Astro-physics Decadal Survey)*, p. 34), solar physics research draws support from diverse sources and the research recently conducted at the McMP uniquely encapsulates this scientific diversity. The education and public outreach programs also run at the McM/P are unique and have national impacts.

Using the 1.6-m Main telescope at the McMP facility are several infrared studies of the Sun, which range from the long-term (13 years of data) sunspot magnetic field strength observations to the studies of the solar atmospheric dynamics of the cold chromosphere that span just several hours of observations. Unique spectral observations of sodium emission from Mercury and the Lunar CRater Observation and Sensing Satellite (LCROSS) impact event, as well as the ultra-high spectral resolution infrared measurements of the atmospheric temperature on Venus, illustrate the planetary astronomy applications of the McMP and its instruments. Measurements of terrestrial HCl molecules have verified the effectiveness of the Montreal protocol. Finally the laboratory determination of new spectroscopic parameters of the ¹³C¹⁴N molecule will enable better analysis of cometary and cool star spectra, and point to the important contribution to fundamental physics by the instrumentation at the McMP facility.

4.2.2 Divestment or Closure of the McMP

The NSF/AST has required NSO to ramp down NSO support for the McMP to minimum operations by the end of 2013 with divestment to follow as soon as practically possible. The McMP was operated by the NSO at this minimal level in FY 2014.

Discontinuing NSO operations can be accomplished by divesting the McMP to other groups or by mothballing or removing the facility. The cost of long-term mothballing of the facility will be estimated. NSO has recently awarded a contract to assess the environmental impact of the divestiture of our facilities at Kitt Peak.

The best, and least costly, path is to find a group or groups willing to assume responsibility for the McMP. To this end, NSO conducted a workshop in early 2013 to identify parties interested in taking over the telescope facility and to discuss the costs and logistics of the transition. Currently, the NSO has a few users that contribute to the cost of operating their experiments at the McMP. To smooth the transition and give other groups time to obtain funding, NSO proposes allowing users that can provide funding and their own support to continue using the facilities with a ramp-down plan of NSO support through FY 2017. Thereafter, it is expected that a consortium of users would assume full responsibility for the operation of the McMP on Kitt Peak as a tenant observatory. This removes the McMP from the NSO "books" and NSF funding,

while providing interested parties more time to raise full operational funding. We have a similar arrangement with the Evans Solar Facility at Sac Peak. A number of issues will arise in negotiating with potentially new operating institutions. Some of the costs of maintaining the McMP are contained in the Kitt Peak National Observatory (KPNO) budget. These include a number of KPNO partial FTEs that provide maintenance and the McMP footprint costs for overall mountain operations. NOAO's long-term plan for continuing mountain operations is also a factor that any new operating institution must consider. In particular, the NSF expects that the NOAO will not be operating telescopes on Kitt Peak (with the possible exception of the Mayall 4-meter) by the end of FY 2015. The NSO is in the process of negotiating a ramp-down of NOAO support of NSO Kitt Peak facilities contained in the shared resources portion of the KPNO budget.

4.2.3 Current Programs

4.2.3.1 The 1.6-m Main Telescope

Synoptic observations from Livingston (NSO) using the McMP have revealed a secular decrease in the mean sunspot magnetic field strength during solar cycles 23 and 24. If this decline continues, it has enormous implications: a weak cycle 24 is one outcome, and an even weaker, or non-existent cycle 25 might also occur. No analogous observations have been made at any other facility, and this data set alone shows the enormous value of the McMP and its infrared capability. Extension to this data set using imaging spectropolarimetry at 1565 nm with the new NAC system is currently underway. We have started an intercalibration program between the McMP and the FIRS instrument at the DST to further understand these secular changes. Much of the infrared spectrum is still barely explored, especially in flares, sunspots, and the corona. The McMP and the NSO Array Camera (NAC) have begun to address these questions with new observations of a powerful X1.8 flare and the magnetic structure of the sunspot superpenumbra using the infrared He I line at 1083 nm, and new observations of the CO lines at 2330 nm and at 4667 nm. Eclipse observations showing the changes in the line shape of the Mn I 1526 nm line with height in the upper photosphere were made during the 2014 partial eclipse.

The research activities at the McMP have several unique applications to the future DKIST facility. Infrared spectropolarimetry tests of polarimetric optics at 4135 nm have been performed at the McMP with direct application to the DKIST cryogenic near-IR spectropolarmeter (CryoNIRSP) instruments. Of critical importance to the DKIST is the ability to perform polarimetric calibrations, and the accepted technique is the correlation technique modeled from the work of Kuhn et al. (1994). The McMP and the NAC is currently the only telescope and instrument combination that can test this DKIST technique in the 3000-5000 nm spectral range. These McMP observations are laying the foundation for studies in atomic physics and subsequent magnetic field measurements.

Telescopic scattered light measurements in the 3000-5000 nm spectral range are being made at the McMP. After Haleakal $\mathbf{\bar{a}}$ was selected as the DKIST site, it became clear that the coronal observations would be limited by telescopic rather than atmospheric scattered light. The state-of-the-art laboratory experiments in telescopic scattered light from dust do not probe the small angle regime nor the wavelength regime where DKIST coronal observations are proposed. Direct measurements of these angles and wavelengths are possible using the McMP telescope.

Preliminary observations at 1565 nm are different from the model fits using 10-micron laboratory data, which have been used to predict DKIST dust scatter. Further observations in the 1-12 micron wavelength region, particularly at 1075 and 3934 nm where the DKIST will measure solar coronal emission lines, will be done at the McMP, and the results will be used to further refine the predicted DKIST scattered light values as well as the cleaning program for the DKIST primary mirror.

The McMath-Pierce is currently the only solar telescope that is equipped to observe the Sun at wavelengths longer than 2.5 microns. The McMP played a key role in the development of the NJIT/BBSO New Solar Telescope Cryogenic Infrared Spectrograph (Cyra). In early 2012, narrow-band filters for isolating solar spectral lines from 3600-4200 nm were ordered for Cyra, and these were installed in the NAC at the McMP and tested. In 2013, a polarimeter system consisting of a rotating quarter-wave retarder and linear polarizers was obtained by the Cyra program and tested at the McMP using the NAC. While the McMP main spectrograph is at room temperature, resulting in a large background at these wavelengths, the NAC was able to make the first spectro-polarimetric maps of a sunspot at 4135 nm during observations in fall 2013 (early FY 2014).

Observing programs to be run on the Cyra instrument are currently being tested on the McMP using the NAC. While the Cyra observations will benefit from a greatly reduced thermal background, exploratory observations at the McMP with the warm spectrograph will have important scientific results. The basic atomic physics involved with producing the Stokes profiles in several atomic lines near 4135 nm (from Fe I and Si I) will be tested using the data from the McMP, and the intermediate coupling theory for the Stokes profile production for these configuration interaction transitions will be tested. Several strange molecular transitions with negative effective Landé g-factors have also been observed. Initial observations of the infrared chromospheric lines in this region are planned for FY 2015. The 3 – 4-micron region observed with the NAC and the McMP have revealed spectral diagnostics arising from the photosphere, chromosphere and corona with magnetic sensitivies that are five to ten times greater than corresponding features in the visible. Thus, the McMP is demonstrating the tremendous potential of the mid-IR for solar magnetic field measurements at the highest sensitivities. With the exploratory NAC observations come experiments designed to enhance the signal to noise of the observation procedure, and important tests of background subtraction and gain correction techniques at this wavelength. These all will be applied to the Cyra observation procedure at the New Solar Telescope, and should result in observations of the magnetic fields in the quiet Sun with unprecedented magnetic sensitivity.

4.2.3.2 The 91-cm East Auxiliary Telescope

At the 91-cm East Auxiliary telescope of the McMP facility, several direct imaging experiments have been run. With a visible CCD and using modern image reconstruction methods, high-resolution images of granulation and sunspots have been taken. Exploiting the excellent infrared qualities of the site, a state-of-the-art two-color QWIP array detector has been used to take unique observations of solar flares in the infrared continuum. The fully remote control capability of the East Auxiliary has allowed observations to be taken from locations like local high-school, and the education and public outreach opportunities for this telescope are currently being explored.

These new flare observations have implications for a new generation of DKIST instruments. With a spatial resolution almost three times greater than the McMP, the DKIST will have the ability to study the time evolution of flare kernels with much greater detail than currently possible. The strange impulsive behavior of the photosphere seen at these wavelengths, where thermal processes are predicted to dominate, is still unexplained. With a plan for an initial PI DKIST instrument, and then a second-generation DKIST imager, studies of flares at these wavelengths will have a large impact on our understanding of the physical processes involved in the particle accelerations.

4.2.3.3 The 88-cm West Auxiliary Telescope

Often used for direct imaging, and thought to have the best image quality of the three telescopes, the West Auxiliary telescope was used for a public outreach event during the partial eclipse of October 2014. A simple Web camera was mounted to view the projected image from the telescope, and fed to a Google-hosted Web page. Viewers from all 50 states and from more than 700 cities in the United States connected to the event, and international viewers from 34 different countries also viewed the eclipse images from the McMP during the event.

4.3 Evans Solar Facility

The Evans Solar Facility (ESF) includes a 40-cm coronagraph that observes the solar corona as well as a 30-cm coelostat that provides Sun-as-a-star integrated light. The Air Force Research Laboratory (AFRL) group at Sacramento Peak provides support for and is the primary user of the ESF 40-cm coronagraph. SOLIS has replaced the spectroheliogram capability of the ESF with full-disk imaging. The AFRL also provides funding for an observer who provides support for operations and data processing as well as for minimal maintenance. The High Altitude Observatory has installed an instrument on the ESF, ProMag, for measuring prominence magnetic fields. This instrument, which is operated by the same observer, is designed to perform spectro-polarimetric analysis of the chromosphere (in particular prominences and filaments) simultaneously in the He I lines at 587.6 nm ("D3"), 1083.0 nm and H-alpha (656.3 nm).

The future of the ESF depends on the interest and support of the existing users. The ramp-down profile NSO has established for activities in Sunspot concentrates the efforts in maintaining the DST functionality to its standard levels. The ESF only receives support whenever a major malfunction appears in the facility. In the event of discontinued support from the current funding partner (AFRL), NSO plans to mothball the facility. This decision will first be in consultation with the NSO Users' Committee.

4.4 Access to NSO Data

4.4.1 Digital Library

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic datasets (daily solar images from SOLIS, GONG data, and a portion of the Sacramento Peak spectroheliograms) over the Internet to the research community. Current NSO Digital Library archives include the Kitt Peak Vacuum Telescope (KPVT) magnetograms and spectroheliograms;

the Fourier Transform Spectrometer transformed spectra, the Sacramento Peak Evans Solar Facility spectroheliograms and coronal scans, and solar activity indices. In addition, NISP archives comprise GONG and SOLIS instrument datasets. GONG data include full-disk magnetograms, Doppler velocity and intensity observations, local and global helioseismology products, and near-real-time H-alpha, far-side, and magnetic-field products.

The near-real-time products are automatically disseminated to various agencies, including AFWA, AFRL, NOAA/SWPC, and NWRA for space weather prediction applications. The SOLIS data archive includes the VSM, ISS and FDP. In 2014, about 32 TB of combined NISP and Digital Library data were exported to over 1,200 users. Additional data sets from ISOON, the DLSP, and the remainder of the NSO/SP spectroheliograms (being digitized at NJIT) will be included in the future. We will also be hosting some non-NSO data sets such as the Mt. Wilson Ca K synoptic maps, the AFRL Air Force Data Assimilative Photospheric flux Transport (ADAPT) magnetic field forecasts and forecasts of the F10.7-cm flux and EUV flux. The Digital Library also hosts the data sets from the DTS Service Mode observing runs.

Since the inception of the Digital Library in May 1998, more than 300 TB of science data files. These figures exclude any NSO or NOAO staff members. The holdings of the NSO Digital Library are currently stored on a set of disk arrays and are searchable via a Web-based interface to a relational database. The current storage system currently has 300 TB of on-line storage. The Digital Library is an important component of the Virtual Solar Observatory (VSO).

4.4.2 Virtual Solar Observatory

In order to further leverage the substantial national investment in solar physics, NSO is participating in the development of the Virtual Solar Observatory. The VSO comprises a collaborative distributed solar-data archive and analysis system with access through the WWW. The system has been accessed approximately a million times since Version 1.0 was released in December 2004. The current version provides access to more than 80 major solar instruments and 200 data sets along with a shopping cart mechanism for users to store and retrieve their search results. The interface has now expanded and in addition to the graphical user interface (GUI), there is an interactive data language (IDL) and a Web service description language (WSDL) interface (e.g., Python programmers). These two interfaces are now the major routes to data search and access through the VSO.

The overarching scientific goal of the VSO is to facilitate correlative solar physics studies using disparate and distributed data sets. Necessary related objectives are to improve the state of data archiving in the solar physics community; to develop systems, both technical and managerial; to adaptively include existing data sets, thereby providing a simple and easy path for the addition of new sets; and eventually to provide analysis tools to facilitate data mining and content-based data searches. None of this is possible without community support and participation. Thus, the solar physics community is actively involved in the planning and management of the Virtual Solar Observatory. None of the VSO funding comes from NSO; it is fully supported by NASA. For further information, see *http://vso.nso.edu/*. Recently, the major effort in the VSO has been the construction of remote mirror nodes for the data set produced by NASA's SDO mission. This

effort is now complete, with one of these nodes is now located at NSO. SDO downloads via the VSO are currently close to a 1TB/day, where the NSO provider is an important download node.

With the completion of the SDO mirror nodes, VSO has resumed the development of spatial searches. Currently, almost all of the data accessible through the VSO is in the form of full-disk solar images. A spatial search capability will allow the user to locate data in a specific area on the Sun delineated by heliographic coordinates. The returned data could be either observations of a restricted area on the Sun, or full-disk data covering the required Carrington longitudes. The spatial search capability requires information on the location of the observational instruments, since current NASA missions such as STEREO are not located near the Earth. In addition to the spatial search capability, the VSO will soon provide access to another 6-12 data sets that have requested to be included. Another active VSO development is an improved usage reporting system. This is challenging, given the distributed nature of the data sets and the access methods available to users.

In the time frame covered by NSO's 2012-2016 Long Range Plan, NSO will continue to be a central component of the VSO.

HT = Hilltop Telescope		PST = Kitt Peak SOLIS Tower
McMP = McMath-Pierce Solar Telescope		PE = McMath-Pierce East Auxiliary Telescope
	Telescope	Comments/Description
NSO/Sacramento Peak – OPTICAL IMAGING &		
High-Order Adaptive Optics	DST	60 - 70-mode correction (two systems, Port 2 and Port 4) Spectroscopy/Polarimetry, 25-45 mÅ resolution, 550 nm-860 nm
Interferometric Bidimensional Spectrometer (IBIS)	DST DST	
Diffraction-Limited Spectro-Polarimeter (DLSP) Universal Birefringent Filter (UBF)	DST	6302 Å polarimetry, 0.09 arcsec and 0.25 arcsec/pixel Tunable narrow-band filter, $R \le 40,000, 4200 - 7000 Å$
Horizontal Spectrograph (HSG)	DST	R \leq 500,000, 300 nm - 1.0 μ m
Universal Spectrograph	ESF	Broad-spectrum, low-order spectrograph, flare studies
Littrow Spectrograph	ESF	$R \le 1,000,000, 300 \text{ nm} - 2.5 \ \mu\text{m}$
Spectro-Polarimeter for Infrared & Optical Regions (SPINOR)	DST	HSG based Spectro-Polarimeter, 450-1700 nm
Rapid Oscillations in the Solar Atmosphere (ROSA)	DST	Imaging system, 350-660 nm
40-cm Coronagraph	ESF	300 nm – 2.5 μm
Prominence Magnetometer	ESF	Spectro-Polarimetry, 587.6, 656.3, 1083.0 nm
Coronal Photometer	ESF	Coronal lines: 5303 Å, 5694 Å, 6374 Å 6374 Å
NSO/Sacramento Peak –O/IR IMAGING & SPEC	TROSCOP	Y
Horizontal Spectrograph (HSG)	DST	High-resolution 1- 2.5 μ m spectroscopy/polarimetry, R \leq 300,000
Facility Infrared Spectropolarimeter (FIRS)	DST	Spectro-Polarimetry; 630.2, 1083.0, 1564.8 nm
Littrow Spectrograph	ESF	Corona and disk, 1 - 2.5 μm spectroscopy/polarimetry
NSO/Kitt Peak – O/IR IMAGING & SPECTROSC	ΟΡΥ	
SOLIS Vector Spectromagnetograph (VSM)	KPST	1083 nm: Stokes I, 2000 $ imes$ 1.1 arcsec, 0.35-sec cadence
		630.2 nm: I, Q, U, V, 2000 × 1.1 arcsec, 0.7-sec cadence
		630.2 nm: I & V, 2000 × 1.1 arcsec, 0.35-sec cadence
		854.2 nm: I & V, 2000 \times 1.1 arcsec, 1.2-sec cadence
SOLIS Integrated Sunlight Spectrometer (ISS)	KPST	380 – 1083 nm, R= 30,000 or 300,000
SOLIS Full-Disk Patrol (FDP)	KPST	High temporal cadence filterograms at 656.28 and 1083 nm
Vertical Spectrograph	McMP	0.29 - 12 μm, R <u><</u> 10 ⁶
NSO Array Camera (NAC)	McMP	1 - 5 $\mu m,$ 1024 \times 1024, direct imaging, and full Stokes polarimetry
		from 1- 2.2 μm
CCD Cameras	McMP	380 - 1083 nm, up to 2048×2048 pixels, high-speed
R Adaptive Optics	McMP	2 – 12 μm
Planetary Adaptive Optics	McMP	0.4 - 0.7 μ m, planetary or stellar sources down to ~3 rd magnitude
Stellar Speatrograph	McMP	at the stellar spectrograph 380 – 1083 nm, R < 10⁵
Stellar Spectrograph Image Stabilizer	McMP	Solar, planetary or stellar use to 7^{th} magnitude for use with the
	IVICIVIE	vertical or stellar spectrograph
Integral Field Unit (IFU)	McMP	$6.25" \times 8"$ field, 0.25" per slice, producing a 20
		long-slit.
Wide-Field Imager	McMPE	Astrometry/Photometry, 6 arcmin field
NSO/GONG – GLOBAL, SIX-SITE, HELIOSEISM	IOLOGY NE	TWORK
Helioseismometer & Magnetograph	California, Hawai`i, Aus-	2.8-cm aperture; imaging Fourier tachometer of 676.8 nm Ni I line; 2.5 arcsec pixels; 1-min. cadence.
	tralia, India,	Full Disk, 1 arcsec pixels; 20-sec. cadence

5 DKIST CONSTRUCTION AND OPERATIONS RAMP UP

5.1 Introduction

On December 15, 2013, the 4meter Advanced Technology Solar Telescope was renamed the Daniel K. Inouye Solar Telescope (DKIST). The renaming ceremony took place at the Haleakalā construction site. The DKIST will be the most powerful solar telescope and the world's leading ground-based resource for studying solar magnetism that controls the solar wind, flares, coronal mass ejections, and variability in the Sun's



Figure 5.1-1. Left to right Jennifer Sabas, Dr. William Smith (AURA), Mrs. Irene Hirano Inouye, Dr. David Lassner (UH), Dr. James Ulvestad (NSF), Dr Valentin Martinez Pillet (NSO).

output. The strong scientific case for DKIST was made in two previous decadal surveys (*Astronomy and Astrophysics in the New Millennium* (2001) and *The Sun to the Earth—and Beyond* (2003)). The recent NSF sponsored *Community Workshop on the Future of Ground-based Solar Physics* (2011) reemphasized the "game changing" science DKIST will enable. The detailed science drivers for DKIST are discussed in numerous publications including the science requirements document (*http://atst.nso.edu/library*). The science drivers lead to a versatile DKIST design that supports diffraction-limited imaging, spectroscopy and, in particular, magnetometry at visible and near- and far-infrared wavelengths, and infrared coronal observations near the limb of the Sun.

A primary scientific objective of the DKIST is to precisely measure the three-dimensional structure of the magnetic field that drives the variability and activity of the solar atmosphere. The energy released in solar flares and coronal mass ejections was previously stored in the magnetic field. The magnetic field is structured on very small spatial scales and understanding the underlying physics requires resolving the magnetic features at their fundamental scales of a few tens of kilometers in the solar atmosphere. The large 4-m aperture of the DKIST, which represents a transformational improvement over existing solar telescopes, opens up a new parameter space and is an absolutely essential feature to resolve structures at 0."025 (20 km on the Sun) at visible wavelengths.

A main driver for a large-aperture solar telescope is the need to detect and spatially resolve the fundamental astrophysical processes at their intrinsic scales throughout the solar atmosphere. Modern numerical simulations have suggested that crucial physical processes occur on spatial scales of tens of kilometers. Observed spectral and, in particular, Stokes profiles of small magnetic structures are severely distorted by telescope diffraction, making the interpretation of low-resolution vector magnetograms of small-scale magnetic structures difficult to impossible.

Resolving these scales is of utmost importance to be able to develop and test physical models and thus understand how the physics of the small-scale magnetic fields drives the fundamental global phenomena. An example is the question of what causes the variations of the solar radiative output, which impacts the terrestrial climate. The Sun's luminosity increases with solar activity. Since the smallest magnetic elements contribute most to this flux excess, it is of particular importance to study and understand the physical properties of these dynamic structures. Unfortunately, even the most advanced and newest current solar telescopes, such as the 1.6-m New Solar Telescope (NST) or the 1.5-m GREGOR, cannot resolve such scales because of their limited aperture size (Table 5.1-1).

A large photon collecting area is an equally strong driver toward large aperture as is angular resolution. Observations of the chromosphere and, even more so, the faint corona are inherently photon starved. The solar atmosphere is structured on small spatial scales and is highly dynamic. Small structures evolve quickly, limiting to just a few seconds the time during which the large number of photons required to achieve measurements of high sensitivity can be collected. Measurements of the weak coronal magnetic fields are essential to understand the physics of, for example, coronal mass ejections, and aid space weather prediction efforts. Measurements of the coronal magnetic field are desperately needed to make progress but are also extremely difficult. The coronal intensity is only 10^{-5} to 10^{-6} of the disk intensity. The polarimetric signal DKIST aims to detect is only 10^{-3} to 10^{-5} that of the coronal intensity. This means that contrast ratios are of the order of 10⁻⁸ to 10⁻¹¹ and, thus, are not too different from what planet detection efforts are facing. The large collecting area and low scattered light properties of the DKIST are essential to achieve the chromospheric and coronal science requirements. The magnetic sensitivity of the infrared lines used to measure coronal fields and the dark sky conditions in the infrared are important motivations to utilize the DKIST for exploring the infrared coronal spectrum. The off-axis design was motivated by the coronal science requirements as well as by technical considerations.

As construction progresses on schedule, NSO is ramping up to DKIST operations. DKIST operations, including data handling and dissemination, will be much more efficient compared to the operations of current NSO or similar facilities. DKIST operational concepts have been developed and will be refined during the ramp-up phase. The community represented by the science working group (SWG) is actively engaged and is providing input to all aspects of DKIST operations planning. New operations concepts build on the lessons learned from recent spacecraft operations such as TRACE, *Hinode* and SDO. Efficient operational modes such as Service Observations will make more efficient use of the available observing time. The NSO Data Center at NSO headquarters in Boulder will provide well calibrated, science-ready DKIST data products to the solar physics community. An open data policy allows for maximum science productivity.

5.2 Daniel K. Inouye Solar Telescope: Construction Project Update

The DKIST is an all-reflecting, 4-m, off-axis Gregorian telescope housed in a co-rotating dome. The DKIST delivers a maximum 300-arcsec-diameter circular field of view. Energy outside of this field is rejected from the system by a heat stop located at prime focus, allowing manageable thermal loading on the optical elements that follow. The telescope also includes a sophisticated wavefront control system, including active optics (aO) for figure control of the primary, active alignment of the critical optical elements, such as primary and secondary mirrors, and an integrated high-order adaptive optics (AO) system designed to provide diffraction-limited images to the focal-plane instruments at the coudé observing stations.

The basic telescope parameters and design for the DKIST and its subsystems have been described in detail in a number of recent publications to which we refer the reader for design details and performance analysis (see *http://dkist.nso.edu/library/pubs*). Additional information can be found on the DKIST Web site, *http://dkist.nso.edu*. The most important capabilities of the DKIST are summarized in Table 5.1-1.

Table 5.1-1. DKIST Key Parameters				
Telescope Property	Specification or Reason for Property			
Aperture	4 meters			
Diffraction-Limited Resolution				
λ = 430 nm	0.022 arcsec			
λ = 1 μ	0.05 arcsec			
$\lambda = 4 \mu$	0.2 arcsec			
λ = 12 μ	0.60 arcsec			
Gregorian				
Off-Axis				
Unobstructed Aperture	No Spider Diffraction			
Clean Point-Spread Function	High Strehl			
Alt-Az Mount				
High-Order Conventional Adaptive Optics	MCAO-Ready Optical Design			
Internal Seeing Control	Thermal Control of Optics and Structure			
Dust Control for Low Scattered Light	Coronal Observations			
Polarimetric Sensitivity	>10-5			
Polarimetric Accuracy	5 x 10-4			
Wavelength Coverage	300 nm to 28 micron			
Facility-Class, First-Light Instruments				

5.2.1 Construction Status

In FY 2014, at the facility site at Haleakalā Observatories (HO), the DKIST completed significant progress on the observatory facilities. The Utility Building, which houses the facility power and thermal support, was completed in December 2014; the principal fluid chillers were installed and electrical work is ongoing in support of the Enclosure and Support and Operations building. The two critical concrete piers were completed during this time: 1) the coudé pier (supports the coudé rotator and hence the feed optics and scientific instruments) and 2) the telescope mount pier (supports the telescope mount assembly and the initial optical systems). Further, the steel support structure for the telescope level (pier cone bents and head ring) were also aligned and completed. The exterior steel support for the lower fixed enclosure was also completed along with the platform lift assembly. Finally, the steel erection for the Support and Operations building began with an anticipated Beneficial-Occupancy-Date in 2016.

Off-site, the Enclosure successfully passed its Factory Acceptance Testing in Spain; the components have been transported to Maui and staged for the start of the Enclosure erection in December 2014. The Telescope Mount Assembly (which is composed of the Telescope Mount and the Coudé Rotator) also passed a milestone in the successful completion of the Coudé Rotator Factory Acceptance Testing; this system has arrived in Maui while the Telescope Mount system will undergo its acceptance testing in February-March of 2015. The M1 mirror blank was accepted in



Figure 5.2-1. Site progress as seen in January 2014 (coudé pier is complete and the first level of the telescope pier is complete with forms set for the second level). The Utility Building is on the right hand side.

January 2014 and completed grinding at the University of Arizona College of Optical Sciences; polishing began in October 2014. The Top End Optical Assembly (TEOA; M2 and Heat Stop) is scheduled for factory acceptance testing in February 2015. For instruments, the Visible-light Broadband Imager (VBI) system was relocated to the Boulder lab. The VBI Red channel fabrication was completed and the initial alignment established. The Cryogenic Near-IR Spectro-Polarimeter (Cryo-NIRSP) passed its Critical Design Review (CDR) phase and entered into fabrication. The Diffraction-Limited Near-Infrared Spectropolarimeter (DL-NIRSP) has also passed its CDR phase and is continuing into fabrication. The Visible Spectropolarimeter (ViSP) completed the optical design for its CDR which will take place in March 2015.



Figure 5.2-2. Site progress as seen in December 2014. Both piers are complete and the lower enclosure steel structure is in place along with a series of the pre-cast panels for the lower enclosure exterior. The platform lift steel is seen immediately to the right of the lower enclosure.

5.2.2 Schedule Status

The top-level DKIST construction schedule is shown in Table 5.2-1. A sub-system view of intermediate milestones is shown in Figure 5.2-3. Current planning targets calendar year 2019 for obtaining the first scientific data with a DKIST instrument. At the end of the commissioning phase each instrument will be tested for compliance with the science performance specifications (e.g., spatial, spectral resolution, polarimetric sensitivity, as appropriate). Training of operations staff will occur during the extended Integration, Test and Commissioning (IT&C) phase. A science verification period performed by the DKIST teams, supported by the instrument partners, will demonstrate the scientific validity of delivered data products. With the conclusion of instrument science verification, the facility will be handed over to operations.

	Table 5.2-1. DKIST Major System Milestones				
Support Facilities	2016-May	Support and Operations Building Beneficial Occupancy			
	2017-Apr	Site Close Out (Apron, Water tanks, drainage, parking, etc)			
	2017-Apr	Coating and Cleaning Facilities Available on Site			
Optical Systems	2015-Apr	Primary Mirror Polishing Acceptance Complete			
	2015-Jun	M1 Cell Assembly Acceptance Complete			
	2015-Jan	TEOA Acceptance Complete			
	2017-Mar	Delivery of Feed/Transfer Optics Complete			
Telescope Mount Assembly	2015-Apr	TMA Mount Acceptance Complete			
	2015-Dec	Begin Site Assembly of Coudé Rotator			
	2016-May	Begin Mount Base Install			
	2017-Dec	TMA Mount Installation Complete			
Enclosure	2014-Dec	Enclosure ready for site assembly and testing			
	2015-Jan	Enclosure AZ track installation, assembly and testing complete			
	2016-May	Enclosure Weather Tight and Internals Complete			
Facility Thermal Systems	2017-Aug	Telescope Mount Thermal System Complete			
	2017-Sep	Install Final Chillers, Re-balance and Tune System			
	2017-Nov	Enclosure Thermal System Complete			
Wavefront Correction	2016-May	Deformable Mirror System Acceptance Complete			
	2017-Nov	WFC System Testing Complete (Boulder Lab)			
	2018-Oct	WFC Coude Installation Complete			
Software	2016-Oct	Data Handling System Integration Release			
	2017-Apr	Observatory Control System Integration Release			
Instruments	2015-Mar	Instrument CDRs Complete			
	2019-Feb	VBI First Light Demonstration			
	2019-Mar	Partner Instrument Commissioning Begins			
	2019-Aug	Start of Science Operations			

5.2.3 Financial Status

Following the Project Re-baseline, the Total Project Cost was established as \$344.1M. To date, the project has received \$243M, \$146M from the American Recovery and Reinvestment Act of 2009 (ARRA) and \$97M from the Major Research Equipment and Facilities Construction (MREFC). The ARRA funding was provided in January 2010 and expires at the end of FY 2015. The MREFC funding is provided annually based on supporting the planned spending and commitments

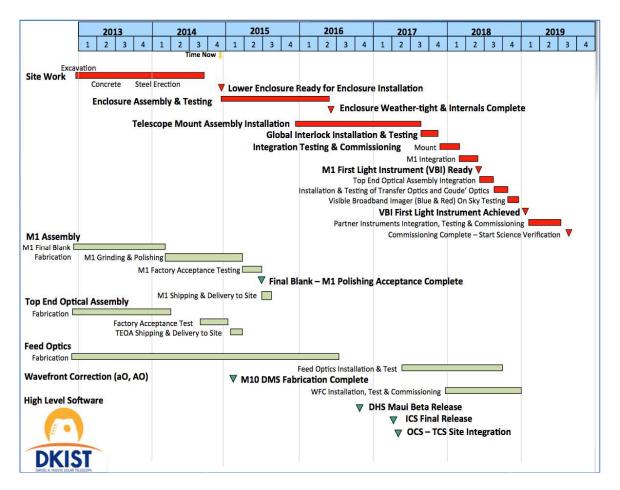


Figure 5.2-3. DKIST sub-system view of intermediate milestones.

through 2019. Due to the delayed start of the site construction, work scope originally designated to be spent as ARRA will not be complete before those funds expire; as a result, the project continues to reorganize the funding allocations to ensure a FY2015 spend-out of all ARRA funding.

At the end of 30 September 2014, the project was maintaining approximately \$40.7M (25% of the remaining project cost) in contingency; this amount provides more than an 80% confidence level for the identified risks.

5.3 DKIST Operations Ramp-Up Phase

In FY 2013-2014, NSO started to ramp up for DKIST operations, while at the same time started the ramp down of current flagship facilities such as the DST and McMP and transferring resources to DKIST operations. The gradual transition of NSO base resources to DKIST operations planning will continue throughout the DKIST construction phase. With the availability of a DKIST operations ramp-up funding wedge in FY15, the operations planning and efforts for implementation of infrastructure necessary for DKIST operations can accelerate significantly and to a level necessary to achieve full operations of DKIST in 2019. A major deliverable of the ramp-up phase is the DKIST Data Center, which will handle processing, archiving, and distribution to the community of DKIST data products. It should be noted that

operations planning and ramp up to operations, including the implementation of a Data Center and a Remote Operations Building, are the responsibility of the NSO but are outside the scope of the DKIST construction project.

We note that the delay of an operational ramp-up funding wedge by one year to 2015 particularly has impacted the development of the DKIST Data Center and the development of detailed operations plans. The recruitment of a Data Center Development Project Manager and Data Center technical staff had to be delayed. This results in a significant risk to achieving operational readiness in 2019.

The ramp-up phase to full-up operations of DKIST will continue through 2019. The staffing plan for the operations phase is as follows. On Maui, a team of approximately 36 FTEs will support telescope operations. Seven scientific FTEs, which at any given time include two postdoctoral fellows, will provide Resident Astronomers (RA) with expertise in DKIST instruments, wavefront correction (WFC) system, and data handling. In addition to the permanent science support staff, science staff and students from partner institutes and international collaborators are expected to spend significant time at the site to support routine observations. A six-FTE staff of telescope operators led by a chief observer will be responsible for daily operations of the telescope. A 15-FTE engineering and technical staff will maintain the telescope systems and instruments and provide operational and safety support as needed. Data handling, computing and system support will be provided by four FTEs. An administrative staff will consist of a site business administrator, one administrative assistant, a safety officer and a buyer/clerk. Additional HR and purchasing support will come from the NSO HQ staff and AURA staff in Hilo. We plan to contract facility support and janitorial services.

At NSO Headquarters in Boulder and at the beginning of full operations in 2019, a science team consisting of staff astronomers, postdoctoral fellows, and graduate students (~13 FTEs) will support the DKIST science operations. This includes user support at the Data Center, the maintenance and upgrades to first-light instrumentation and the development of second-generation instruments. The initial prioritization by the DKIST Science Working Group of second-generation instrumentation will be reviewed by the SWG and the broader community and, if necessary, re-prioritized to take into account recent scientific developments and progress of the field. During the ramp up to operations phase (2015–2019), the CDR phase of the selected, highest priority second-generation instrument will be concluded. The instrument development program will continue the successful model currently applied at NSO, where an NSO scientist either leads the instrument development effort, collaborating closely with university or international partners, or a university PI takes the lead and teams with an NSO scientist(s) in developing the instrument.

5.3.1 DKIST Data Center Development

In order to further leverage the substantial national investment in solar physics, NSO will develop at its new headquarters location in Boulder a DKIST Data Center (DC), which will eventually serve both DKIST and NSO Integrated Synoptic Program (NISP) communities. The Data Center will implement the data processing, storage, archiving, and dissemination tasks. The DC will provide computational resources in support of DKIST science goals and broadening

community engagement, data use, and inquiry in solar phenomena. The DC will be the central repository of DKIST scientific and ancillary data, and will produce calibrated, value-added data and data products via the execution of a robust, operational workflow system. In addition, the DC will manage the full lifecycle of this raw and processed data, enabling advancement through discovery and provenance tools and the publication of open-source implementations of published processing and analysis algorithms.

While a NISP Data Center component currently is well established and operating, the DKIST Data Center has yet to be developed. The data volume produced by DKIST will be of much higher volume and significantly more complex in terms of product types, reduction steps, and dimensionality than synoptic data. In order to understand the magnitude of the task to develop (and eventually operate) the DKIST Data Center with components located on Maui and at NSO HQ, it is worthwhile to review how data from current ground-based solar facilities, such as the DST, are handled and processed. The national and international high-resolution ground-based facilities are operated in PI mode. The raw data collected during an observing run, including all calibration data, are simply provided to the PI on hard disk or tape. It is the PI's responsibility to perform all necessary data processing, including calibrating the data. In some cases, the NSO and its partners have provided calibration and reduction software to aid in the data processing. Due to the limited assistance that could be provided, every user must become an expert user of the facility's complex instrumentation. It often takes many years of experience for a user to arrive at the necessary proficiency and, with limited support, build an individually owned tool box for performing calibrations. Furthermore, the carefully calibrated data usually remain with the PI and are not generally available to the community for other scientific investigations. It is easily understood then that science productivity is needlessly limited due to the lack of any data handling support or any broader scheme to provide a unified collection of the high-resolution data.

The DKIST operations model is designed to significantly increase science productivity by providing both support for service mode operations and a Data Center that facilitates access to the acquired and processed data. In limited ways, the DKIST Data Center development effort will draw from previous experiences by other projects. In FY 2014, the DKIST Data Center Scientist visited and consulted the various groups involved in the management and processing of large data volumes, including *Hinode*, SDO, ALMA, and NISP. The NSO has enlisted valuable expertise through the SWG Data Center Sub-Working Group chaired by Neal Hurlburt (LMSAL).

A significant challenge is the formal definition of Data Center requirements that capture the needs of a broad segment of the community. The requirements development effort will continue to progress through FY15 and attempts to balance the sometimes very different approaches and experiences of the space-based and ground-based facilities and respective communities. While the space-based community prefers a limited set of standardized data products, users of ground-based facilities value the flexibility and ability to customize observations and subsequent data processing to enable discovery. The Science Working Group ans its DC Sub-working Group is developing the critical science plan which will inform the definition of DC requirements. In FY 2014, a set of draft requirements documents was developed by the Data Center Scientist. The documents were reviewed internally. The Data Center Program Manager was hired in August, 2014 and has since taken the lead in driving requirements development to a conclusion.

Additional Data Center hires in FY14 included an IT Systems Administrator and a Senior Software Engineer. A Solar Data Calibration Engineer is expected to be hired in FY15. During operations, a technical staff of approximately 9-10 FTEs will support the Data Center systems and implement and operate the data production pipelines for DKIST. The ramp up to full operations staffing for the DKIST portion of the Data Center and DKIST science support will continue during 2015–2019. This is achieved by reprogramming existing resources currently supporting DST and Tucson operations and applying additional resources for DKIST operations ramp up. FY15 milestones, relevant to the DKIST Operations award, are listed in Appendix E2.1.

5.3.2 DKIST Service Mode and Operations Tools Development

In order to achieve the highest possible operational efficiency and guarantee maximized highimpact scientific output, NSO will, for a significant fraction of the available observing time, abandon the traditional model of scheduling observing time, in which only one PI has exclusive access to the telescope during a fixed block of observing time and with some help from the observing staff performs the observations. Instead, service observations that allow for flexible scheduling will be implemented. Scientific observing requests will be efficiently pooled, queued and executed only when solar conditions, target availability and seeing conditions, are suitable. Only the expert DKIST operations staff will operate the telescope, instruments and all associated support systems. Service time is dynamic and the observatory staff is responsible on a daily basis for real-time decisions regarding what programs out of a scientific merit-ranked list are executed and what instruments will be operated. The service mode does not require the physical presence of the proposal PI. Remote participation in observations by the PI is enabled via telecommunication equipment.

The service mode allows making efficient use of target availability, weather conditions and technical readiness, and supports a broad range of different programs. This mode is amenable to target-of-opportunity observations and can be used to perform (long-term) synoptic programs, and does allow for joint/coordinated (campaign) programs or other programs where special time constraints are given (e.g., rocket launch, balloon or space experiment). The service mode also supports maintenance and engineering tasks or special calibration measurements. Those often can be performed during weather conditions that are not suitable for science observations. Service mode provides flexible scheduling tools that avoid usage of prime observing time for these calibration measurements. To fully support service-mode observing, the on-site observatory staff will have a number of key scientific and engineering "actors" that conduct and support the observations. These include the resident astronomer, operators, engineers, instrument scientists, and a wavefront correction scientist. The RA is the final authority for daily scheduling and execution of observations. Instrument and wavefront correction scientists are expert users of complex instrument and adaptive optics systems who ensure that these systems are properly calibrated and operated with consistent performance according to specification, as well as provide support to users in preparing and conducting observations. In contrast to the PI-modebased operations of "highly flexible" instrument setups at current facilities, DKIST's emphasis on service mode operation of facility-class instruments in conjunction with an open data policy will enable DKIST to provide consistent data products that can be processed, archived and disseminated by the NSO Data Center.

The development of service-mode operations, which includes the creation of organizational structures (e.g., Telescope Time Allocation Committee (TAC)), training of staff (resident astronomers and operators) as well as the development of a significant number of tools to support service-mode operations (e.g., experiment generator, experiment tracking tool, full-disk context capabilities) is a sizable task. Initial service-mode experiments have been performed at the DST in FY14 and will likely continue in FY15. Community acceptance and feedback have been overwhelmingly positive. The campaign has increased user demand for observing time (data products) and brought new users to the DST.

Important lessons and requirements for the DKIST service-mode operations are summarized in the Service Mode Experiment report (A. Tritschler et al., internal NSO Technical Report, 2012). A set of operations tools necessary to support efficient service mode operations has been specified by the operations scientist. Detailed requirements will be drafted and reviewed during FY15. Design and development of operations tools will begin in FY15.

Coordinated DKIST service-mode observations with future solar space observatories, such as the Japanese led Solar-C mission, must be carefully conceived in the early phases of the projects. One can ideally envisage a joint Time Allocation Committee to fully exploit the synergies between these two telescopes. TAC procedures and policies have been drafted and were discussed with the Science Working Group.

5.3.3 Maui Remote Operations Building

The Remote Operations Building (ROB) on Maui will serve as the operational center of the DKIST. In contrast to the DST in Sunspot where all facilities and support infrastructure are on site and near the telescope, the DKIST site does not include all the necessary office, laboratory and data handling infrastructure. The function of this ROB will be similar to Gemini's Base Facility in La Serena Chile, and the NOAO/NSO offices in Tucson, AZ by providing a facility from which the science, operations and maintenance activities of the Maui-based DKIST engineering can be performed. Unlike the other AURA base facilities, however, the DKIST construction budget provided no funding for the acquisition and construction of a ROB. A concept was put forth for NSF review and approval for the construction of the ROB.

The DKIST ROB's primary function will be to provide offices and work areas for the scientists and postdoctoral researchers (permanent and guest), non-site operations and engineering personnel and administrative staff not required to work at the summit on a day-to-day basis. In addition to the work space, the ROB will support specialized functions including: hosting a remote control room for remote operations of summit instrumentation; data processing and preparation for data transfer to the NSO Data Center in Boulder; and providing a platform for future upgrades to DKIST instrumentation.

AURA has conducted an extensive review of possible lease sites and sites for construction of the ROB. In previous material submitted to the NSF, ten options were presented for consideration. Most of these options did not meet the basic requirement of the ROB as presented in the ROB



Figure 5.3-1. Rendering of the DKIST Remote Operations Building on Maui.

design study previously provided to the NSF. Of these options, only three offered a potential for meeting the basic requirements of the ROB. These three options are discussed in the design study document. Additionally, AURA has prepared an extensive financial analysis of these three options which includes not only the cost of the lease or cost of the construction but also operations and maintenance (O&M) costs for each option.

The results of these analyses show that construction of the ROB on a property in Pukalani is by far the most cost effective option for the life of the DKIST operation. This property is adjacent to the University of Hawai'i Institute for Astronomy (UH/IfA) building. In addition to direct cost savings, the proximity to the IFA building offers several intangible benefits including shared use of laboratory space and equipment, improved proximity to the DKIST summit and increased scientific productivity due to collaborations with the nearby UH/IfA solar and instrument partner group. Proximity to the UH/IfA Advanced Technology Research Center (ATRC) provides a convenient and very cost effective access point required for transferring the large amounts of data from the summit to the ROB.

In addition, only minimal additional infrastructure would be required. The UH's data handling system, which brings raw observational data down from the telescope site, has a terminus at the IfA building. AURA would only need to link to that terminus for data to be directed to the ROB for processing and analysis by the on-site staff at no additional cost.

Furthermore, the location of a building next to another facility dedicated to the advancement of astronomical research recognizes the significance of the DKIST project. Consequently, this ROB location would promote and facilitate the collaboration among the DKIST and IfA staff as well as establish a central, unified operations center for the astronomical community, visiting science and political dignitaries and the public at large.

In FY 2014, AURA/NSO conducted the design phase of the ROB. The design is 75% complete. A solid cost estimate has been established as part of the design process. Pending NSF review and approval, construction of the ROB is expected to commence in FY15.

5.4 DKIST Science Working Group and Science Requirements

The community is represented and supports the DKIST effort through the DKISK Science Working Group (SWG) and its Sub-Working Groups, including the coronal, data center and operations working groups. The SWG is chired by Mark Rast of the University of Colorado, Boulder. The current membership of the SWG is listed in Table 5.4-1. With construction well underway and instrument capabilities well defined, the focus of the SWG is shifting to operations planning, data handling and processing requirements, data products and dissemination and the development of the Critical Science Plans (CSP). The CSP will be executed during the first one-to-two years of operations. The SWG annual meeting for calendar year 2014 was held on 23 – 26 October 2014, i.e., early FY15. The agenda included:

- Project, instrument, data center updates;
- Discussion of scientific impact of changes to instrument capabilities: Cryo-NIRSP context imager, VTF spectral resolution;
- Decision on final filter for VBI red channel;
- Definition of proposal review procedures;
- Further definition of essential data products;
- Critical Science Plans science and observational strategies.

The meeting was highly productive in the sense that SWG members proposed and presented detailed and well thought out CSP observing plans specifically tailored to DKIST instruments. Many of the CSP observation plans made use of the DKIST capability to combine several instruments for simultaneous observations. In general, SWG members demonstrated a detailed understanding of instrument capabilities derived from previous SWG presentations by instrument partners and instrument descriptions provided on the DKIST Web site. The occasional misinterpretation of instrument and telescope capabilities was identified and clarified during the process. During FY15, the SWG will continue to refine and further detail CSP experiments and focus on engaging a broader section of the community in CSP development. Current CSP topics and community leaders include but are not limited to:

Dynamo processes and magnetohydrodynamics

- Small-scale photospheric magnetic fields: formation, structure, dynamics (Brown).
- Turbulent dynamo: Hanle effect imaging of the quiet-Sun (Bellot).
- Wave generation and propagation (Rast).
- Magnetoconvective modulation of solar luminosity (Criscuoli).
- Sunspots: umbral and penumbral structure and dynamics (Tritschler).
- Flux emergence and active region formation (Katsukawa).

Magnetic connectivity and energy flows in the outer atmosphere

- The chromosphere/corona connection (Cao).
- Spicule physics (McIntosh).
- Formation, evolution, and eruption of non-potential configurations (Parnell).
- Multilayer magnetometry and atmospheric heating (Socas-Navarro).
- Coronal waves and energy fluxes (Cranmer).
- Energy and magnetic helicity in coronal structures (Judge).
- Prominence morphology, connectivity, and life cycles (Scullion).
- Infrared survey of the solar atmosphere (Penn).

Flares and eruptive activity

- Flare precursors in the lower atmosphere.
- Magnetic field connectivity and changes in flares (Qiu).
- Flare electron diagnostics in visible light (Cauzzi).
- Flare foot points at their fundamental scales (Fletcher).
- <u>CMEs</u>

The SWG agreed in the following route and schedule to develop detailed observing proposals with strong community involvement:

October 2014	SWG meeting, CSP leads present and discuss Step 1 (Title, Team, Science,		
	Observational strategy)		
December 2014	AGU call for community participation in CSPs		
April 2015	AAS/SPD Town Hall, Indianapolis		
Summer 2015	Call for community participation at EGU?		
Summer 2015	CSP leads formulate more detailed observational requirements for CSPs		
November 2015	Further CSP discussion at SWG meeting		
Summer 2016	Special SPD session, Boulder		
Fall 2016	Conversion of CSPs into observing proposals by leads		
November 2016	Proposals presented to SWG		
Summer 2017	Special SPD session, Jackson Hole		

TABLE 5.4-1. DKIST SCIENCE WORKING GROUP							
						Start	
Count	Last Name	First Name	Affiliation	Country	Status	of term	Term
1	Bello-Gonzales	Nazaret	KIS	Germany	Member	2014	2 years
2	Cao	Wenda	NJIT	US	Member	2013	2 years
3	Cauzzi	Gianna	AO	Italy	Member	2005	2 years
4	Cranmer	Steve	SAO	US	Member	2014	2 years
5	DeForest	Craig	SWRI	US	Member	2002	2 years
6	Deng	Yuanyong	NAOC	China	Member	2013	2 years
7	Fletcher	Lyndsay	U. Glasgow	UK	Member	2002	2 years
8	Hurlburt	Neal	LMSAL	US	Member	2011	2 years
9	Judge	Phil	HAO	US	Member	2003	2 years
10	Katsukawa	Yukio	NAOJ	Japan	Member	2014	2 years
11	Martens	Piet	MSU	US	Member	2014	2 years
12	McIntosh	Scott	HAO	US	Member	2011	2 years
13	Parnell	Clare	St. Andrews	UK	Member	2011	2 years
14	Qiu	Jiong	MSU	US	Member	2011	2 years
15	Rubio	Luis Bellot	IAC	Spain	Member	2002	2 years
16	Scullion	Eamon	QUB	UK	Member	2014	2 years
17	Socas-Navarro	Hector	IAC	Spain	Member	2002	2 years
18	Vidar Haugen	Stein	ITA	Norway	Member	2014	2 years
19	Rast	Mark	U. Colorado	US	Member	2013	2 years
20	Goode	Phil	NJIT	US	Co-I		
21	Knoelker	Michael	HAO	US	Co-I		
22	Rosner	Robert	U. Chicago	US	Co-I		
23	Kuhn	Jeff	IFA	US	Co-I & Instrument PI		
24	Berger	Tom	NSO	US	Ex-Officio		
25	Rimmele	Thomas	NSO	US	Ex-Officio		
26	Casini	Roberto	HAO	US	Instrument PI		
27	Lin	Haosheng	IFA	US	Instrument PI		
28	Schmidt	Wolfgang	KIS	Germany	Instrument PI		
29	Woeger	Friedrich	NSO	US	Instrument PI		

5.5 Existing Collaborations: Adaptive Optics and the Cyra Instrument

NSO/DKIST continues to develop national and international partnerships. A strong partnership with the New Jersey Institute of Technology (NJIT) and the Kiepenheuer Institute for Solar Physics (KIS) for development of adaptive optics and multi-conjugate adaptive optics (MCAO) continues. Solar MCAO will provide diffraction-limited imaging over a large field of view, a capability that NSO is pursuing with high priority for implementation at DKIST as part of second generation instrument development. The 1.5-m GREGOR on Tenerife and the 1.6-m NST at Big Bear Solar Observatory (BBSO) serve as pathfinder telescopes for the development, implementation and science demonstration of MCAO. NSO, NJIT and KIS AO teams are collaborating closely and are jointly funding the effort.

In FY 2014, development of a "limb-AO" system at the DST was concluded. This is the first time AO was demonstrated for faint limb structure such as prominences. The DKIST SWG requested that this capability be made available at DKIST during the early operations phase. In response, the limb-AO system was developed in collaboration with New Mexico State University (NMSU), Las Cruces and was led by a NMSU graduate student.

In FY 2014, the DKIST construction project vigorously pursued collaboration with the UK. A UK consortium led by Queen's University Belfast, a current instrument partner at the DST, has successfully proposed to UK funding agencies for the development of visible cameras for the DKIST. A kick-off meeting is scheduled with the UK partners for early 2015.

Matt Penn (NSO) is a CoI for the CYRA instrument at BBSO. CYRA is a prototype of the DKIST Cryo-NIRSP, which will be fabricated by the DKIST CoI institute UH/IfA. NSO involvement in the development, testing and science verification phase of CYRA provides valuable experience that will be applied to DKIST Cryo-NIRSP.

6 NSO INTEGRATED SYNOPTIC PROGRAM

The NSO Integrated Synoptic Program (NISP) was formed in July 2011, and combines the Global Oscillation Network Group (GONG) and the Solar Long-Term Investigations of the Sun (SOLIS) programs. These two programs have similar scientific goals and share a number of technical approaches, so the combination of the two has resulted in improved system efficiency and increased scientific synergy.

When DKIST is completed, the combination of the DKIST and the NISP will provide a complete view of solar phenomena on a range of spatial scales from tens of kilometers to the full disk, and on time scales from milliseconds to decades. In particular, NISP is a long-term and consistent source of synoptic solar that observes the Sun as a whole globe over solar-cycle time scales. While space missions, such as SOHO and SDO, also observe the entire solar disk, they cannot match the long-term coverage provided by NISP, which started in 1974 with the advent of the Kitt Peak magnetograph, Sac Peak flare patrol, and spectroheliograms. In addition, space missions are vulnerable to the effects of solar flares and CMEs, cannot be repaired, and are extremely expensive. These qualities make NISP invaluable as a source of data for national space weather needs. The recent National Academy report on *Solar and Space Physics: A Science for a Technological Society* strongly supported synoptic solar physics as an essential component of the science needed for space weather.

6.1 NISP Instrumentation

The NISP/GONG component is an international, community-based program that studies the internal structure and dynamics of the Sun by means of helioseismology—the measurement of resonating acoustic waves that penetrate throughout the solar interior—using a six-station, world-circling network to provide nearly continuous observations of the Sun's five-minute oscillations. The instruments obtain 1K × 1K 2.5-arcsec pixel velocity, intensity, and magnetic flux images in the photospheric Ni I 676.7 nm line of the Sun every minute, with an approximately 90% duty cycle, enabling continuous measurement of local and global helioseismic probes from just below the visible surface to nearly the center of the Sun. Near-real-time continuous data, such as 10-minute cadence, high-sensitivity magnetograms, seismic images of the far side of the Sun, and 20-second cadence 2K × 2K H-alpha intensity images are also available. These real-time data are used by the US Air Force Weather Agency (AFWA), and NOAA's Space Weather Prediction Center (SWPC) for space weather forecasts. AFWA provides NSO with funding towards GONG operations. In addition, the Air Force Research Laboratory (AFRL) uses GONG data to drive their ADAPT forecast of the solar magnetic field using data assimilation.

NISP/SOLIS has three main instruments: a vector spectromagnetograph (VSM) capable of observing full-disk vector and line-of-sight magnetograms in the photosphere and chromosphere, a full-disk patrol (FDP) imager, and an integrated sunlight spectrometer (ISS) for observing the high-resolution spectra of the Sun as a star. The VSM produces 2K × 2K longitudinal and vector magnetograms constructed from full Stokes polarization spectra at a resolution of 200,000 in the Fe I 630.15/630.25 nm line pair, and longitudinal magnetograms in the Ca II 854.2 nm line core

and wings. This allows the VSM to provide simultaneous photospheric and chromospheric magnetic field measurements, a powerful combination for understanding the structure of magnetic fields in stellar atmospheres. The VSM also produces chromospheric intensity (equivalent width) images in He I 1083.0 nm, which are used for identification of coronal holes. The FDP can take observations with a temporal cadence as short as 10 seconds in several spectral lines including H α , Ca II K, He I 1083.0 nm, continuum (white light), and photospheric lines. The ISS observations are taken in nine spectral bands centered at the CN band 388.4 nm, Ca II H (396.8 nm), Ca II K (393.4 nm), C I 538.0 nm, Mn I 539.4 nm, H α 656.3 nm, Ca II 854.2 nm, He II 1083.0 nm, and Na I 589.6 nm (D line) with a resolution of 300,000. The ISS can observe any other spectral lines within its operating range. Hardware for the guider in the VSM was installed in early June 2013, completing the SOLIS hardware project. The software for the VSM guider is now complete for corrections in right ascension, and the declination loop will be closed in early 2015.

SOLIS was relocated from Kitt Peak to the University of Arizona agricultural campus in Tucson in August 2014 in preparation for the NSO relocation to Boulder and the divestment of the McMP. NSO is seeking a permanent site to locate SOLIS. Under consideration are Big Bear Solar Observatory in California, Haleakalā on Maui, Mauna Loa on Hawai'i (or Big Island), and other candidates that have responded to a request for information. The final choice will balance cost, logistics, and site quality.



Figure 6.1-1. Removal and transport of SOLIS from Kitt Peak (left and middle photos), and installation at the new SOLIS shelter in Tucson (right).

6.2 NISP Data Products

The NISP provides a large number of data products to the community. In addition to the products mentioned above, data processing pipelines produce global helioseismic frequencies, localized subsurface velocity fields derived from helioseismic inversions, synoptic maps of the solar magnetic field, potential field source surface extrapolations of the magnetic field in the corona, vector magnetic field maps of active regions produced from inversions of the Stokes profiles, and the total global magnetic flux. These data products are important for understanding the Sun and its activity cycle and related space weather. They also can be used for understanding the impact of stellar activity on habitable planets. In addition, the experience of NISP in pipelining a large number of data products, and in performing inversions, can be applied to the development of the DKIST data processing and analysis system. NISP scientists use insights

from their own research to monitor and improve the quality of NISP data and to develop new data products. Most recent examples include error estimates for synoptic magnetic maps, synoptic maps of vector fields, sunspot field strengths derived from separation of Zeeman components of spectral line profiles, and merged Doppler velocity images from early GONG data prior to 2001. Within the next few years, NISP is expected to provide vector magnetic field observations in the chromosphere using the Ca II 854.2 nm line. This will provide a much fuller picture of the structure of the magnetic field in the middle solar atmosphere, where the field direction changes from primarily vertical to horizontal as it forms the magnetic canopy. This transition takes place in the solar atmosphere near the location where the solar wind is accelerated. These future chromospheric vector magnetic field observations would be extremely important not only for understanding the origins of space weather for planets in our solar system, but also for testing the theories of the generation of stellar winds and their consequences for the habitability of planets around other stars. A combination of the ISS and VSM data would allow us to deconvolve the solar-disk average characteristics of the Sun in terms of activity across the disk. The latter would bring a new understanding of stellar disk-integrated parameters. It is also expected that progress will be made on a new synoptic network with instrumentation capable of providing both vector magnetic field and Doppler data in multiple wavelengths by 2020.

Research into the use of local helioseismology to detect active regions before they emerge is continuing. In addition, helioseismic measurements of subsurface vorticity as a forecast of flare activity are being developed. Both of these approaches hold out considerable promise of success, but also have proven to be challenging. Global helioseismology has been tracking the evolution of large-scale flows, including the north-south meridional flow and the zonal flow known as the torsional oscillation. These flows are intimately connected with the dynamo mechanism that produces the solar magnetic field and associated activity. For example, the timing of the migration of the zonal flow has proven to be a good indicator of the future behavior of sunspot activity. Current observations suggest that the next activity cycle, number 25, may be even weaker than the current cycle. NISP scientific staff are participating in a NASA Grand Challenge Project to constrain dynamo models of the solar cycle using internal flows from GONG and surface magnetic field measurements from SOLIS. Improvements to the quality and reliability of the NISP/GONG helioseismic maps of active regions on the solar farside are in development. These maps have become key tools for space weather forecasters, particularly as the NASA STEREO mission enters a phase of degraded telemetry dues to the orbital positions of the spacecraft.

6.3 NISP Status

The NISP/GONG component continues to operate, but with noticeably increasing system failures due to reduced funding, which has resulted in deferred maintenance. The data acquisition system (DAS) is being upgraded and replaced with a PC-based system similar to that used in the SOLIS component; this is an example of the improved efficiency that NISP provides. In addition, GONG is now able to obtain data in near-real time from all six sites including Learmonth. This development has resulted in a net financial saving and reduced the latency between data acquisition and reduction of the helioseismology products. New and less expensive entrance windows for the GONG system have been acquired and are now being installed.

NISP has received substantial but unstable support from the US Air Force Weather Agency since 2009, when AFWA provided \$650K to develop and install H-alpha filters in the GONG shelters. AFWA subsequently provided \$800K of operational funds for two years, but was forced to cut that support by 50% in 2013 due to the Federal Sequestration Act. In February 2014, NISP was informed that there would be no more support from AFWA but then, in September 2014, AFWA unexpectedly provided \$800K. The future of this support is very uncertain.

NISP is also providing data to the Space Weather Prediction Center in Boulder. SWPC is funded by NOAA and uses GONG and SOLIS data as input to drive a predictive model of terrestrial geomagnetic storms. SWPC certainly recognizes the value of the data and the need for its availability, and negotiations with the new SWPC Director are underway to define the level and method of support. We note that SWPC declared GONG data essential during the 2013 Government shutdown episode. While it is unlikely that SWPC will be able to directly supply funds, NOAA should be able to supply the resources as an in-kind contribution, such as assigning NOAA data processing staff to NSO or operating the Mauna Loa GONG site. Similarly, NISP data are used to drive models hosted by NASA's Community Coordinated Modeling Center (CCMC), and all of the NASA solar space missions use NISP data for context and supporting observations. A proposal to NASA's recent opportunity for Heliophysics Infrastructure and Data Environment Enhancements was successfully funded for three years, indicating that NASA also recognizes the importance of the NISP data products.

Using helioseismology, NISP produces estimates of the magnetic field on the farside of the Sun that is turned away from the Earth. The estimates provide a signal that new active regions have emerged that will appear on the Earth-facing side up to two weeks in advance, as seen recently in the appearance of the giant sunspot AR2192. This tool has become a key ingredient in space weather forecasts, and its importance is increasing as the STEREO mission ages, and as the STEREO spacecraft move into positions where it is impossible to acquire the data.

New remote site infrastructure is now developed and research at the US Air Force Research Laboratory (AFRL) has shown that the assimilation of farside data into the construction of synoptic magnetic field maps greatly improves the quality of the maps as it reduces the errors at the edge of the map that would otherwise contain older data from 28 days earlier. In September 2012, the AFRL data assimilation system, known as ADAPT, was installed at NSO/Tucson and will be used by NOAA/SWPC to drive the geomagnetic storm prediction system discussed above. NISP magnetograms are the primary source of the data that drives ADAPT. The public release of ADAPT should occur early in 2015, and new data products to use ADAPT to forecast the 10.7-cm radio flux and the EUV flux are in development. These products are essential for forecasts of satellite drag.

As noted earlier, in August 2014, the NISP/SOLIS instrumentation was relocated from KItt Peak to the agricultural campus of the University of Arizona, located in the middle of Tucson. NISP has operated the GONG engineering systems at that location, known as the "GONG Farm" since 1991, and SOLIS itself was originally integrated there as well. A new shelter has been constructed and a separate structure based on a shipping container now houses the ISS and computer systems. The relocation of SOLIS to Tucson is a necessary first step towards the eventual installation of the instrumentation at a remote site, which is part of the overall NSO transition. Carrying out the relocation to Tucson well in advance of the final move has several advantages:

- Operational costs are reduced since Kitt Peak fees are no longer required.
- Commute time to instrumentation site is reduced from 3.5 to 0.5 hours per day.
- Remote operations methods can be more easily developed.
- VSM upgrades can be carried out more efficiently since downtown facilities are nearby.
- Lower impact of McMP divestment on NISP.

The ISS and the VSM have resumed operations at the GONG Farm, with data quality that is actually somewhat superior to what was obtained at Kitt Peak. The relocation of the ISS provided an opportunity to perform maintenance on the optical system, which increased the throughput. The VSM data have been improved apparently because the Farm has better daytime seeing compared to Kitt Peak, at least during the cooler seasons of the year. The accuracy of the pointing of the SOLIS mount was also improved by the reduction of some alignment errors that had existed on Kitt Peak. On the other hand, the Full-Disk Patrol (FDP) instrument, unfortunately, suffered significant water damage during the relocation and needs to be mechanically refurbished before its newly completed Visible Tunable Filter can be installed.

The VSM will be upgraded in early 2015 to install the new Stokes vector modulator for the chromospheric Ca II 854.2 nm line. This will allow the VSM to provide vector magnetic field measurements in the chromosphere, a unique data product that should greatly increase our ability to extrapolate the solar magnetic field into the heliosphere. During the upgrade, a number of additional tasks will be performed to improve the reliability of the instrument in advance of its deployment to a remote site. These tasks include the replacement of cooling fans; improvements to the access to various internal components; and the installation of a new power supply to allow the use of control boards that do not require the VxWorks real-time software control system. The complete removal of the need for a VxWorks license also requires the installation of a new camera (already in house) for the ISS, but will provide a major costs savings and greatly ease the long-term maintenance of SOLIS.

The NISP Data Center continues to develop processing pipelines that integrate the five NISP instruments — GONG/H α , GONG/Doppler + magnetograms, SOLIS/VSM, SOLIS/ISS, and SOLIS/FDP. This makes the lessons of the NISP Data Center a useful input to the development of the DKIST Data Center. A multi-wavelength, multi-resolution synoptic map pipeline that processes both SOLIS and GONG data is now in place, and will be extended to produce synoptic maps of GONG H α data. The SOLIS processing now occurs in a centralized NISP infrastructure isolated from SOLIS legacy hardware dependencies, removing what had been the most problematical SOLIS system, and exploiting the pipeline expertise developed in the GONG program. This is another example of NISP efficiency.

The utilization of near-real-time NISP data products by space weather forecasters is increasing. The hourly GONG magnetic field synoptic maps are now routinely used by NOAA/SWPC to drive their forecasts of the solar wind and geomagnetic storms. The H α images from GONG are used by the US AFWA and SWPC for flare monitoring. AFWA also uses the high-cadence GONG magnetograms, and the AFRL receives a special ten-minute GONG magnetic field data

product tailored for ingest by their ADAPT data assimilation system to predict the surface solar magnetic field. Both NOAA and the AFRL use the maps of the far-side magnetic field produced from GONG helioseismic data. Forecasts of F10.7 and EUV flux, based on NISP data, are being developed for use in satellite drag calculations.

NISP goals in FY 2015 will be dominated by the transition to Boulder and the need to maintain operations in the face of substantial staff turnover. Due to the transition and budget uncertainties, so far NISP has lost five key staff members who have moved on to other projects outside of NSO. This has created a need to redistribute important tasks among the remaining staff, and to recruit new personnel who will then require training as fast as possible.

Beyond staff relocation, there are three major transition tasks for NISP in the FY15-16 time frame: relocate SOLIS to a permanent remote site, move the NISP Data Center to Boulder, and relocate the two GONG engineering instruments to Boulder. A major decision in FY 2015 will be selection of the permanent location for SOLIS. Leading candidates at this time are Haleakalā, Mauna Loa, or Big Bear, with other possibilities arising from a recent request for interest. The time frame for permanent relocation is expected in 2016. The plan for the Data Center transition is now being developed, with an initial schedule target of summer of 2015 to begin the installation of hardware in Boulder. Note that the data reduction for the AFWA H α images is already located in the Cloud, and a prime Data Center task is to transition the NOAA/SWPC magnetic field processing into the Cloud as well. Since the NISP network sites are geographically independent of Tucson, their operation and the resulting supply of space weather data should not be interrupted during the transition. Maintaining NISP operations and the supply of data to an increasing user base with time-critical requirements in the face of a complex and uncertain transition process is the major challenge for NISP in FY2015-2016.

6.4 A Multi-Purpose Global Network

Synoptic data is vital both for the success of the DKIST and for society in general. Both the aging of GONG and the single-site nature of SOLIS has led the solar physics research community to call for a new improved synoptic network. While NSO has previously proposed for a network of three VSM instruments similar to the one currently on SOLIS, it is now thought that a better solution would comprise a new multi-purpose network. Such a network would open new realms of scientific research, and provide input data that are vital for space weather operational forecasts. Since the NSF/AST Division Portfolio Review recommends a substantial reduction in NISP support, the funds for developing and operating a new network will need to have major support from the space weather community, including agencies such as AFWA, NASA and NOAA.

There are a number of new scientific research directions in solar physics that motivate the desire for a new ground-based network. For example, there is a growing need for multi-wavelength measurements to provide observations of wave propagation and the vector magnetic field as a function of height in the solar atmosphere. For helioseismology, we now know that inclined magnetic fields in the solar atmosphere convert the acoustic waves into various types of MHD modes and change the apparent phase of the waves, which produces incorrect inferences of the sub-surface structure below active regions. For magnetic field measurements, it is essential to know the direction and strength of the field above the photosphere for accurate coronal field extrapolations, and to reliably remove the azimuthal ambiguity. Our understanding of the generation, transport, and evolution of the solar magnetic fields would make significant progress with the availability of continuous long-term multi-wavelength observations. Simultaneous helioseismic and magnetic observations will also bring a better understanding of propagation of acoustic waves in the presence of magnetic fields, thus bringing us closer to forecasting the subphotospheric properties of magnetic fields. In addition, irradiance measurements such as those provided by the Precision Solar Photometric Telescope (PSPT), which are important for climate research, would be improved with additional spectral bands and more continuous coverage.

It is important to note that existing and future space missions often propose to combine helioseismic observations made from different vantage points to better map layers inside the Sun such as the tachocline. While we have long benefited from continuous Earth line-of-sight helioseismic observations from space that could be combined with observations made from a different perspective, the best way to secure in the long run such observations is through a ground-based network similar to GONG. The ESA/NASA Solar Orbiter mission (launch 2017) will provide helioseismic observations made from a variety of perspectives including from out of the ecliptic. These observations will be made at particular mission orbits that are of interest for the study of the meridional flows near the poles and will occur well into the last phases of the mission (late next decade). Combining such data with observations made from the Earth line-ofsight will bring new insights about fundamental ingredients of the dynamo problem. Similarly, the combination of magnetic field observations from different perspectives allow disentangling complex projection effects that occur when observing crucial locations of the Sun such as the solar poles. SOLIS-like synoptic vector observations and Solar Orbiter similar measurements can be combined to clarify the distribution and strength of the magnetic fields at the solar poles. We thus remain convinced that these opportunities will surely enhance the value of a ground-based synoptic network such as the one proposed here by NSO.

In addition to the research role of a network, space weather operational forecasts rest on the foundation of synoptic solar observations. Agencies such as AFWA and NOAA/SWPC need reliable and continuous sources of solar data, and are already using NISP facilities as a source of surface magnetic fields, H-alpha intensity, and helioseismic far-side maps. A new network that provides multi-wavelength observations would increase the quality of information available for space weather and is an efficient and cost-effective solution to a multi-agency requirement.

There is considerable international community interest in establishing a new network, as demonstrated by a workshop that was held in Boulder in April 2013 to discuss and gather input on science requirements, capabilities and instrumentation. About 60 scientists and engineers either attended the meeting or expressed interest, representing space weather agencies, solar physics research institutes, observatories, government agencies, and international organizations. Most of the presentations, along with the participant list, can be found at *https://www2.hao.ucar.edu/docs/2013-synopticnetwork*. An article reporting on the workshop has been published in *Space Weather* (Hill, Thompson, and Roth *Sp Wea* **11**, 2013). The International Astronomical Union (IAU) has recognized the importance of synoptic observations of the Sun by creating a special Working Group that is chaired by a scientist from NSO (A. Pevtsov).

The instrumentation in a new network should not be a single device to provide all observations, but should comprise individual specialized instruments on a common pointing platform. This approach has several advantages:

- Fewer compromises for scientific requirements within a single instrument.
- More flexibility in funding and schedules.
- Ability to have different instrument suites at different sites to exploit specific observing conditions (e.g., coronal, radio observations).
- Relaxation of stringent scientific requirements for space weather forecast data.
- Lower initial costs need pointing platform, infrastructure and one instrument.

The NSO, with HAO and the Kiepenheuer Institut für Sonnenphysik (KIS) in Germany, is developing the concept, and KIS has obtained funding through the SOLARNET program to develop the Scientific Requirements Document and to carry out an evaluation of instrumental concepts. Sanjay Gosain, an NSO/NISP scientific staff member, has been hired by KIS to do this work and is currently in a joint NSO/KIS position. NSO, along with KIS and other partner institutions, will develop a full proposal for a new network in the next two years. While the NSF Mid-Scale Instrumentation Program (MSIP) would be an appropriate proposal opportunity, the construction of the DKIST may preclude the awarding of another major project to the NSO. A more realistic funding path may be via a KIS-led European proposal. Additional US agency partners are likely to be AFWA, NOAA/SWPC, and NASA. In addition, the Atmospheric and Geospace Sciences (AGS) Division of the Geosciences Directorate in the NSF supports space weather research, which necessarily uses solar synoptic data as inputs for models.

NSO is participating in the European SPRING (Solar Physics Research Integrated Network Group) effort, which has filled a position at KIS to evaluate instrument concepts for the network with Dr. Sanjay Gosain, an NSO staff member. KIS has held two workshops so far to discuss the project with partners. The Web sites for these meetings are at

http://www3.kis.uni-freiburg.de/~mroth/spring.html and

http://www.astro.sk/SOLARNET_2ND_WORKSHOP/solarnet/first_announcement .

An approximate timeline of the network effort is:

- 2014 2016 Work with KIS, HAO and other partners to develop concept.
- 2014 2016 Advocacy for agency, international, and research partnerships.
- 2016 Submit baseline infrastructure and initial instrument proposal to the NSF MSIP and possible European opportunities.
- 2017 2020 Assuming success, begin development of infrastructure and first-light instrument hardware.
- 2015 2018 Continuing advocacy with AFWA, NOAA, NASA, NSF/AGS, etc.
- 2021 Initial deployment.
- 2021 2026 Operations, and additional instrumentation development.

7 EDUCATION AND PUBLIC OUTREACH AND BROADENING PARTICIPATION

With the decrease in NSO base funding in FY 2013 NSO had to reduce its Education and Public Outreach (EPO) efforts in FY 2013 and FY 2014. We, however, remain committed to undergraduate, graduate, and postdoctoral training, areas in which NSO has been most effective. We will support other outreach areas as funding and staff time permit.

NSO is also committed to increasing the diversity of the solar work force. We focus our efforts on expanding participation by underrepresented groups in our student and teacher research programs as well as staff recruitment. To this end, we participate in the Fisk-Vanderbilt Masters-to-PhD Bridge Program, the Akamai Workforce Initiative (AWI) on Maui, two Partnerships in Astronomy & Astrophysics Research and Education (PAARE) programs, and with New Mexico State University graduate programs. In addition, we are working closely with the University of Colorado, Boulder (CU) in the program they recently implemented to enhance the number and training of solar graduate students.

7.1 Goals and Metrics

The primary NSO EPO objectives and goals in priority order are:

- To help train the next generation of scientists and engineers through support for undergraduate and graduate students, postdoctoral fellows, and close collaboration with universities and the DKIST consortium.
 - Continue our successful REU program.

Each REU student provides a program assessment, gives a talk on their work and writes a final report (which can be viewed at *http://eo.nso.edu/*).

○ *Metrics* –

- (1) Number of excellent students persuaded toward solar research.
- (2) Number of students helped toward a science/engineering/computer career.
- (3) Increased diversity in the REU program.
- Strengthen our Summer Research Assistantships (SRA) for graduates program.

Our involvement in the Akamai Workforce Initiative Program has increased the number of mentors by including engineers. The metrics are the same as above. We have made more of our indirect earnings and carryover funds available for student and postdoctoral support.

• Increase the number of thesis students and postdoctoral fellows working at NSO.

The move of the NSO directorate site to the CU campus will strengthen this area by giving access to more top notch graduate students and by providing an attractive locale for postdoctoral fellows. NSO continues to be involved in the training of postdocs and graduate students. We currently have two postdoctoral research associates: Fraser Watson and Dirk Schmidt both joined the NSO staff in FY 2013. Watson has been comparing sunspot data from the McMath-Pierce with spectropolarimetric sunspot observations from the DST to allow for crosscalibration of the two instruments being used, as well as allow for some analysis into the the DKIST capabilities. Schmidt is the current DKIST Postdoctoral Fellow; his research focuses on high spatio-temporal resolution observation techniques and in particular adaptive optics and MCAO. After spending five years as a postdoc with the NSO adaptive optics program, Jose Marino was promoted to Assistant Scientist in July 2013 and continues to focus on AO and MCAO, including DKIST wavefront correction. Brian Harker spent five years as a postdoc with NISP and was promoted to Assistant Scientist in February 2014; he continues to play a significant role on the NISP interior products working group (PWG). Sanjay Gosain joined NSO as a postdoc in 2011 and was promoted to Assistant Scientist in early FY 2014. Gosain has been productive with his scientific research using vector magnetic field observations and has a co-lead role for the design, construction, and installation of a new NISP/SOLIS modulator for chromospheric vector magnetic field measurements. NMSU graduate student Greg Taylor defended his PhD thesis on adaptive optics in May 2014, with Thomas Rimmele as his thesis advisor. Thomas Schad was a 2006 NSO REU student working with Steve Keil; he defended his PhD thesis in 2013 as a joint University of Arizona/NSO grad student with Matt Penn as his thesis advisor. Tom is currently a postdoc at the University of Hawai'i Institute for Astronomy, collaborating with NSO instrument projects related to the DKIST. Sarah Jaeggli received her PhD in 2011 from the University of Hawai'i (Haosheng Lin, thesis advisor); she was an REU student with Matt Penn in 2003, worked as a visiting grad student at NSO/SP with Han Uitenbroek for part of her dissertation research which included commissioning of the Facility Infrared Spectro-polarimeter (FIRS) on the DST. She is now a postdoc at Montana State U. and continues to collaborate on NSO instrumentation projects. Teresa Monsue (Fisk-Vanderbilt Masters-to-PhD Bridge Program) completed her master's thesis and started on her PhD in fall 2014 using GONG data; Frank Hill and Keivan Stassun (Vanderbilt U.) are her advisors. Matt Penn currently is a research advisor for NJIT physics graduate student Xi Yang. Yang's thesis project will use 4135 nm spectropolarimetry with the BBSO/NST/Cyra cooled spectrograph instrument to measure quiet-Sun magnetism with high precision. In early FY 2015, NSO arranged to provide support for CU/LASP graduate student Courtney Peck, who will work on projects that aim to understand the utility of high-resolution DKIST observations in solar spectral irradiance studies. Serena Criscuoli and Friedrich Woeger will be advisors to Courtney, in addition to her CU thesis advisor Mark Rast.

- Metrics –
- (1) Number of students who successfully complete their PhD based on NSO data.
- (2) Number of successful postdoctoral fellows pursuing careers in solar science.
- (3) Increased diversity in these programs.

• Continue collaboration with the Akamai Workforce Initiative (AWI) Program on Maui for workforce development.

This effort is going very well. The Akamai Workforce Initiative is a program started by the Center for Adaptive Optics (UC Santa Cruz) and provides students and graduates in Hawai'i with technical training, then places them in internships. We have sponsored four workshops on Maui for Akamai program graduates—the most recent in November 2012 and in November 2013. Since 2010, ten Akamai graduates have participated in NSO programs. Five of the students have worked on DKIST projects, including one Native Hawaiian. One was hired on the DKIST project staff in 2011 (James Linden), and in October 2014, Chriselle Galapon, a recent University of Hawai'i mechanical engineering graduate and an AWI graduate intern, was hired by NSO/DKIST as a Thermal Systems Engineering Assistant.

In summer 2014, Akamai graduate student Stacey Sueka continued her work with advisor David Elmore in Boulder on implementing the NSO lab spectro-polarimeter. We expect to recruit up to four Akamai interns in summer 2015.

The NSO is committed to continuing its partnership with the AWI Program and has formally pledged to provide \$25K per year of support for three years beginning in FY 2015.

• Metrics –

- (1) Akamai trained personnel available for the DKIST Maui work force.
- (2) Increased diversity available for NSO hires.
- To develop K-12 teacher training and student training programs to advance knowledge of science and technology.
 - The NSO will investigate remote observing in cooperation with interested K-12 schools across the country for IR flare observations on the McM/P facility's East Auxiliary Telescope. Recent work with local high school student Nick Irvin from Cienega generated much interest in the local Tucson community with a front-page article in the Tucson newspaper. Dublin School, a private high school from New Hampshire, will work with the McMP facility next to develop a program suitable for high school students.

In order to develop ties with citizen scientists across the country and the world, the NSO is involved in an experiment to study the upcoming total solar eclipse in 2017, also known as the Great American Eclipse. The project idea is to involve up to 100 citizen scientists with simple data collection and then to use this data to develop a scientifically unique movie which probes the dynamics of the inner corona for the first time.

\circ Metrics –

- (1) Number of observing remote observing runs by high schools.
- (2) Number of science fair type projects using remote data.
- (3) Number of citizen scientists involved in the eclipse experiment.

- To increase public understanding of the Sun, both as a star and as the driver of conditions on the Earth, as well as understanding of the related disciplines of optical engineering, electronics and computer sciences, as applied through the DKIST and other NSO projects.
 - Increase the relevance and content of our WWW outreach.

NSO Web pages were recently redone to include more outreach. The outreach effort for the June 2012 solar eclipse and transit of Venus, as well as a number of partial solar eclipse programs run by NSO to engage the public in October 2014, were highly successful. This area needs more work, but is resource limited.

• Develop outreach materials for both classroom and public distribution.

NSO is working with NOAO EPO and UH Maui College and local middle and high school teachers to develop a program for Maui. We have asked NOAO EPO (supported with NSO funding) to lead this effort.

• Complete our Solar System Model and the handout materials that accompany it.

The New Mexico Museum of Space History in Alamogordo is working with NSO to continue support of the model and has expressed interest in the NSO Visitor Center after NSO has departed Sac Peak.

- To increase nationally the strength and breadth of the university community pursuing solar physics.
 - Work closely with our DKIST university partners and other groups to recruit and help diversify the community of scientists doing solar research.

This has started in the form of a joint program, the George Ellery Hale Collaborative Graduate Education Program (CGEP) involving the University of Colorado, New Jersey Institute of Technology, University of Hawai'i (CU/NJIT/UH) and NSO. Details about this program are presented in Section 7.2 that follows.

• Establish close ties with additional universities to provide NSO thesis students.

Currently, ties include New Mexico State University, the University of Arizona, University of Hawai'i, and Vanderbilt University for thesis students, and we now have an alliance with CU for both faculty and graduate students.

7.2 NSO and the CU-Led G.E. Hale Collaborative Graduate Educational Program

A crucial aspect of the Colorado University proposal to host the NSO headquarters was the development of the George Ellery Hale Collaborative Graduate Education Program (CGEP) in collaboration with the UH and the NJIT. The CGEP is a new component in the various educational efforts NSO has traditionally developed to train the future generations of solar astronomers. While the continued REU and SRA programs have provided a constant flow of undergraduate students to NSO, the CGEP will focus on the graduate level with participating

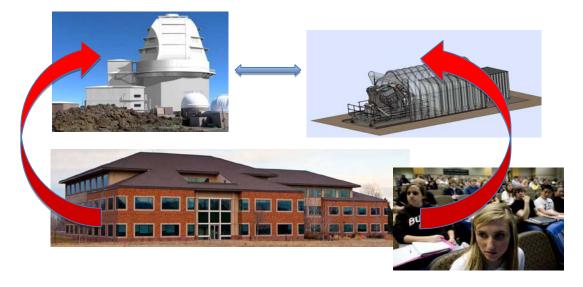


Figure 7.2-1. The relocation of NSO into a University campus and the participation of our scientists in the various academic activities, including the CGEP, will offer a unique opportunity to train the future generation of solar astronomers in the DKIST era.

universities to complement existing programs. Integrating NSO scientists (and engineers) into the academic and outreach missions through teaching at the graduate level in courses offered in the CGEP—but also in traditional courses—is a key aspect of the NSO mission and vision in preparation for the DKIST era.

The CGEP addresses the mismatch between the need for graduate level teaching in solar and space physics and the ability to meet that need at any single institution in the US. Solar physics is fundamentally a multidisciplinary field; it links with fields as diverse as stellar astronomy and plasma physics. Progress in understanding problems of increased relevance, such as how stars and planets are magnetically connected, represents a formidable challenge that requires a combination of disciplines hardly found in a single campus. The CGEP represents an effort to provide a collaborative framework among various university campuses and provide through telepresence education a complete graduate program in solar and plasma physics.

Two CGEP courses have been taught already and used to better understand the challenges posed by distance education. Promoting an inquiry-based learning via telepresence methods does have specific programmatic and technical needs that must be understood before consolidating the program. These two courses have been used as part of the necessary learning process. They have used the Cisco WebEx meeting environment, which has proven useful for many of the goals of the program but has also shown some limitations. WebEx was particularly good at highresolution sharing of lecture slides and the recording of lectures. It was less well suited to intersite discussion and interaction. This was largely due to the inherent VoIP audio delays. A better technical solution is being considered as a result of these two inaugural courses. For the first course (2013), the host site was the Department of Astrophysical and Planetary Sciences at CU, with the course titled "Solar and Stellar Magnetism" and 27 students from Colorado, Hawai'i, New Mexico and New Jersey. One of the lecturers was NSO astronomer Han Uitenbroek. The recorded courses can be downloaded from http://zeus.colorado.edu/astr7500-toomre/. The second course, entitled "Magnetospheric and Ionospheric Response to Solar Output" (2014), was hosted at NJIT and attended by 19 students. The CGEP experience has reached a point where a discussion of all interested Universities should occur to define a joint formulation of a graduate curriculum in solar and plasma physics. Institutional responsibilities must be defined and funding sources for a more interactive telepresences system (such as Cisco TelePresence) identified. The contents of the curriculum and the ownership of course modules must be discussed as well. To this end, CU and NSO plan to host a meeting in early 2015 of all the interested institutions and universities to define the path forward. While this may delay the offering of the third CGEP, it will help consolidate the program. Broadening the definition of the CGEP to include other stakeholders is also under consideration. The NASA Living with a Star initiative has been contacted and has expressed interest in the G.E. Hale CGEP initiative. The AURA Member Representatives also offer a perfect ecosystem in which to expand the program, in particular in preparation for the exploitation of the DKIST. NSO plans to visit a number of AURA institutions (but not exclusively) to promote interest in the CGEP and the possibilities offered by the telescope facility being built in Hawai'i.

7.3 Goals for 2015: An Augmented NSO EPO Program

NSO has conducted in the past a vigorous education and public outreach program, with an emphasis in training students in their early careers. The NSO REU program mentored 37 students over the past 6 years in various areas of solar research and astrophysics instrumentation. Of these students, 35 have either entered graduate school or are still in their last years of their undergraduate program. Our success rate for admission into graduate programs far surpasses the average rate for physics BS recipients, showing how motivated NSO's REU participants have been. The summer research program performed at NSO over this period of time has resulted in 69% of the participants presenting posters and oral contributions to meetings (such as SPD/AAS, AGU, etc.) and 27% of them co-authoring a refereed publication. These REU students came from a diverse list of universities spread all over the country, with some natural preference for southwest States (in particular AZ, NM and TX). This vibrant program has been executed mostly at our Tucson and Sunspot sites but it is naturally being extended into our new sites in Maui and Boulder. In 2014, NSO supported five summer research assistants. Two graduate students were Boulder based, one originally recruited within the Akamai program and the other from CU, and three undergraduates, two at Sac Peak and one in Tucson. It must be stressed that the demand for opportunities to do a research oriented educational experience at NSO has historically been high. The number of applicants has steadily increased from about 50 in 2008 to more than 100 in the last REU call. However, the limited funds available and the number of NSO's mentors enrolled in this program sets the success rate to less than 10%.

In the DKIST era, NSO will continue to offer research-based opportunities for students but with an increased focus at the graduate and postdoctoral levels. Our collaboration with CU through the CGEP will strengthen the graduate component of our program. We are investigating ways in which a stable offer of postdoc positions can be made available to the community. The CU proposal to host the NSO headquarters already included provisions in this direction (one 2-year postdoc every year), but a more DKIST-oriented effort is needed.

To maintain our commitment at the undergraduate level, NSO has submitted an REU proposal for the years 2015 and 2016 for which activities will be developed mostly in Tucson and Sunspot. During these two years, we will discuss with partners in the Boulder Solar Alliance how NSO can best integrate into joint REU program developed at our new headquarters site. The recently submitted REU proposal includes a total of 8 NSO mentors with Matt Penn (Tucson) as PI and Han Uitenbroek (Sunspot) as co-PI. A new component of the proposal is the inclusion of an external evaluator who will assess the quality of the program and its success. This person will interview the mentors and the students near the end of each summer session and provide suggestions for improving our program. If funded, a total of 8 students, 4 in Tucson and 4 in Sunspot, will participate in the NSO REU program. As it has been traditional in the past, common activities—such as visits to the NSO managed observatories—including all of the summer students from the various NSO sites will be organized to provide a richer and more complete research experience.

NSO has successfully collaborated with the Akamai Worforce Initiative (AWI) for over a period of 4 years. AWI concentrates in nurturing the workforce needs in areas such as astronomy, remote sensing, and other technology industries in Hawai'i. Students from the Hawai'i Colleges and students raised in Hawai'i who are at other US colleges are given the opportunity to participate in activities related to the above mentioned research areas. NSO has sponsored four workshops since 2011 that have been used to increase the participation of Hawaiian students and recent graduates, especially Native Hawaiian and other underrepresented groups, in NSO. During these one-week workshops, Akamai students become familiar with the scientific and technical needs of the various projects performed at NSO. An interesting aspect of the Akamai initiative is that it includes as active mentors NSO engineers —in particular DKIST construction staff— as a large portion of the interest from the Hawai'i colleges is technically oriented. From our participation in the Akamai initiative, NSO has hired a variety of personnel, from thermal engineers for DKIST construction to laboratory polarization experts, an aspect crucial for the DKIST calibration. Interns for the NSO summer program where also recruited through the Akamai workshops.

Akamai is at a transition point and in 2015 it is planning to make a number of changes. Their priority will concentrate on rising funding for summer apprenticeships/internships. They have submitted proposals to the AFOSR and to the NSF and they have also contacted the major astronomically related construction projects on the islands, DKIST and TMT, for support. NSO has expressed a commitment to continue support for the Akamai initiative during the period 2015-17 at a level similar to that provided in the past (\$25K/year). NSO will also continue to provide mentors and projects for Akamai apprentices, either on Maui or at one of our mainland sites. An additional avenue for collaborating opens up with the move of our headquarters to Boulder. The Institute for Scientist & Engineer Educators (ISEE, California), that integrates the Akamai initiative, has a chapter in Boulder that will create opportunities for graduate students and other professionals to participate in professional development activities, and further

strengthen our collaboration. As the UH is integrated in the CGEP, the role of the AWI in this program is being discussed among CU, AWI and NSO.

Finally, and in order to further augment NSO's EPO program, we are planning to offer in 2015 two positions with primary responsibilities of promoting our projects and research to a broader audience. Due to a flat funding profile over the last three years, NSO has not been able to preserve the FTEs that were once allocated to EPO activities. This has to change. With our world-class facility being built on Maui, public awareness of the effort represented by DKIST and its scientific achievements must be given adequate publicity. These positions will also promote existing NSO programs in both education and public outreach in close collaboration with the NSO staff. They will support existing NSO education programs at the K-12, undergraduate (REU) and graduate (Akamai and CGEP) levels at schools across the country, and will manage and update the NSO social media presence. We are also expecting these positions to play a role in developing and updating existing solar physics Visitor Centers, and help develop new ties to the citizen science, amateur astronomy and national planetarium groups.

7.4 Increasing Diversity

The NSO relocation of its headquarters to Boulder and its partnership with the University of Colorado (CU) is a unique opportunity and key toward enhancing diversity at the NSO and the solar physics workforce. The NSO embraces the ways in which CU proposes to work with us to promote diversity in future generations of solar astronomers which include the following:

- Participation in CU SMART (included in the Colorado Diversity Initiative) program (*http://www.colorado.edu/GraduateSchool/DiversityInitiative/undergrads/smart/details.html*) that offers about 25 students per year a ten-week opportunity to conduct research under the guidance of a faculty mentor. Conversations are on-going to have NSO staff members as mentors in this program.
- Integration of NSO's REU program into the program led by LASP and that includes the REU programs of all of the institutions within the Boulder Solar Alliance (BSA). The gender statistics of the LASP REU program show that about 53% of the participants are female (similar to NSO's REU program) and 16% from minorities (NSO's REU program is 8%). The existing LASP REU program ends in 2015, when they will submit a new proposal to continue the training of undergraduates. NSO has started conversations with the LASP REU coordinator to see how we can establish a collaborative framework for NSO's summer activities together with the BSA.
- The Collaborative Graduate Education Program CGEP) as described in Section 7.2. The CGEP represents a clear venue to achieve diversity goals as NSO will have access to students not only from CU, but from 4 other Universities spread throughout the country (University of Hawai'i, New Mexico State University, Montana State University, and New Jersey Institute of Technology).

The NSO sees the CGEP as a great opportunity to access a diverse audience that includes Hawai'i. A workshop is planned this year involving the 5 interested

Universities to establish a curriculum compatible with existing curricula at those institutions (and that have a much reduced scope). NSO plans to actively participate in this workshop to express the needs we understand the DKIST era will have.

Finally, the Akamai Workforce Initiative (AWI) has recently been established as a new synergy between the NSO and CU that will serve to enhance the diversity of our workforce. The Akamai program represents a clear venue for bringing STEM students from underrepresented groups into the NSO workforce. Akamai is an innovative enterprise that supports the US astronomy and remote sensing workforce in Hawai'i. NSO has been benefiting from the Akamai program with a remarkable list of successful students and more permanent hiring's made in Maui and in Tucson/Boulder.

The following is a list of institutions that currently maintain an interest in the Akamai Program.

- University of California Santa Cruz (Coordinator)
- University of Hawai'i
- Thirty Meter Telescope International Observatory
- Air Force Maui Optical & Supercomputing Site
- National Solar Observatory, Maui
- Mauna Kea Observatories
- Hawai'i Island Industry
- University of Colorado Boulder

Note that the only continental US University on this list (excluding the Coordinator) is CU Boulder. In a recent visit to Boulder with AWI partners to discuss future activities, Lisa Hunter (Akamai Coordinator at UC Santa Cruz) organized a meeting with CU and NSO to discuss the enormous potential of the Akamai program that is yet to be fully realized. The discussion reaffirmed that there are unexplored possibilities that can be leveraged and from which we all can benefit and enhance diversity of our workforce. In particular, conversations are now ongoing about the possibility of NSO/CU/Akamai internships and Professional Development Programs (PDP). (Information about existing PDPs already involving CU is available at *http://isee.ucsc.edu/programs/pdp/index.html*.) This was an unanticipated opportunity that readily shows how our presence on the CU campus offers rich and varied the possibilities for increasing the diversity of the solar physics workforce.

8 THE NSO TRANSITION PLAN

The construction of a world-class facility such as the Daniel K. Inouye Solar Telescope (DKIST) on the island of Maui in Hawai'i and the distribution of data to the solar community demand a major restructuring of the National Solar Observatory (NSO). The Observatory has been based traditionally at two operating locations, Sacramento Peak in Sunspot, New Mexico—site of the Dunn Solar Telescope (DST) — and in Arizona, with NSO headquarters in downtown Tucson and the McMath-Pierce Solar Telescope (McMP) at Kitt Peak. The NSO is undergoing a major transformation that will change this landscape. On the one hand, for efficient use of the Maui facility, NSO is developing an operations team in Hawai'i and, on the other, the data acquired with DKIST, at a rate of 10 TB/day, require complex analysis pipelines and easy access by the community. To maximize interactions with the community, NSO is forging close links with other astronomy related labs at CU and is establishing venues for participation in academic activities to ensure close proximity with the new generation of astronomers.

Relocation of the NSO Integrated Synoptic Program (NISP) to the new Headquarters in Boulder is an integral part of our transition plan. The major effort needed to develop the DKIST Data Center will be coordinated with the relocation of the NISP data distribution system using the same CU cyber infrastructure, ultimately to form the *NSO Data Center*. The NSO Data Center will provide the community with access to the most detailed and sensitive observations of the Sun, as well as access to relevant, co-temporal, context information from our star. The transformation of the NSO Integrated Synoptic Program, however, is more profound than what the relocation to CU-Boulder implies. The NSF/AST Portfolio Review Committee has proposed that SOLIS, a component of NISP, serve as a context imager for DKIST. In order for SOLIS to perform this role, NSO is considering relocating SOLIS to an adequate astronomical site that offers satisfactory observational overlap with the DKIST operating windows. While the future site for SOLIS (currently in Tucson) has not been firmly established, the benefits from a proximity to DKIST are enormous from a scientific point of view.

As NSO builds a presence in Boulder and Maui, the NSO transition also includes plans to ramp down our presence at Sacramento Peak and in Tucson. This transition is expected to take place over the next five years with consolidation of the Boulder HQ completed by 2017 and development of the DKIST operations team finalized after the end of construction in 2019.

This section describes the main aspects of this transition including an estimate of the costs that we will incur.

8.1 Benefits from the Transition

Overarching scientific goals directly linked to our mission motivate NSO's transition. A primary objective of the transition is to develop the operations team for DKIST at a location (Maui) where no previous NSO presence existed. Efficient distribution of a combination of data from the NISP and DKIST programs through the NSO Data Center also represents a major driver for the relocation to a unified HQ.

Since the start of the DKIST project, it's been clear that an effort of this magnitude calls for strengthening the links between the existing solar community and the future generation of astronomers. This demands an increased presence of Solar Physics in the University community. Thus the umbrella that encompasses DKIST operations, Data Center development, and the training of the next generation of solar astronomers is what has defined the NSO transition in its present form, which called for a relocation of NSO HQ to a University campus. To this end, AURA posted an announcement of opportunity for selecting a new NSO HQ that would consolidate NSO personnel into a single location. With this consolidation AURA pursued the following goals:

- i. To optimize the scientific and operational management of NSO facilities and daily operations including DKIST, NISP, and NSO Data Archives.
- ii. To maximize the benefits to the community of the NSO as provider of the prime groundbased O/IR facilities for the US solar physics community.
- iii. To further the NSO role in supporting research, in developing new instrumentation, and providing data for new frontiers of heliophysics (such as, for example, space weather and solar-stellar connections).
- iv. To enhance the role of the NSO in the education and diversity of future generations of scientists and engineers for astrophysics and heliophysics research in the United States.

Eight institutional candidates responded the solicitation. They all offered, and is some cases proactively promoted, increased solar and astronomical presence in their faculty programs. A selection committee carefully ranked the proposals and the AURA Board made a final decision in September 2011. A resolution was passed that selected the University of Colorado in Boulder as the new NSO HQ site. The process also included NSO's staff input that played a critical role in the final selection.

A unified HQ will offer clear benefits in terms of managing a relatively small institution that has been traditionally separated between two sites, a recurring observation from the community. Additionally, there are more subtle scientific benefits that can be expected from this consolidation to an HQ at a single site. The long-standing division of two sites has prevented synergistic approaches between the scientists at both locations (with some notable exceptions). The Sun is a complex system where the relevant physical scales are tightly coupled. Small-scale effects, such as localized magnetic energy releases, generate large-scale processes that connect our star with the planets in the Solar System, including Earth. The technical capabilities needed to observe the complete range of spatial and temporal scales involved are very demanding. In practice, the instruments needed to observer the Sun at high-spatial resolution are substantially different from instruments that observe the large scales and the full solar disk. This distinct separation of the instrumentation used to cover these scales also results in different data analysis and interpretation techniques that inevitably generate an artificial separation between the two communities: the high-spatial resolution community and the synoptic community. NSO is one of the few institutions worldwide with expertise in both areas. NSO leads the development of AO techniques that allow telescopes to reach the diffraction limit and observe the smallest details that they are capable of detecting. At the same time, NSO's synoptic program is unparalleled in both the broad set of data products it offers and its temporal coverage. Having scientists from these two main NSO programs located in the same building will foster an environment that provides ample room for serendipity discoveries. This synergistic atmosphere will be amplified by the diversity of solar institutions located in Boulder, including the Laboratory for Atmospheric and Space Physics (LASP) that is collocated with NSO in the SPSC building.

NSO's transition is a complex process that involves personnel relocation, divestiture of existing sites and the creation of operations teams that provide access to our facilities and data to the community. The task is enormous and requires a proper managerial approach including an accurate budget, realistic timelines, as well as risk analysis and mitigation strategies. The transition is currently being discussed at the NSO Directorate that includes the NSO Director, the DKIST Associate Director, the NISP Associate Director, the DKIST and NISP project managers, the NSO business administrator and the NSO assistant administrator. AURA Human Resources (AURA/HR) frequently assists the NSO Directorate — and the NSO Director in particular — with issues related to the transition. A Transition workshop was organized in May 2014 to discuss various aspects of the process including the potential risks and how to best address them. Table 8.1-1 provides the most immediate risks we have identified so far and potential mitigation strategies.

8.2 Components of the Transition. Roles and Responsibilities.

The NSO transition has two major milestones: the relocation of the NSO HQ to the CU Boulder campus and the start of regular operations of DKIST on Maui. As we ramp up our presence in Boulder and Maui, NSO will phase out operations at its Kitt Peak and Sac Peak sites and at the HQ in Tucson. One of the major challenges we face is the dovetailing of ramping up our presence at the new sites while we ramp down our presence in Arizona and New Mexico. As requested in the NSF/AST solicitation for the management of the Observatory, and as described in our 2015–2024 Cooperative Agreement (CA) proposal, telescope operations at the two Mainland observatories must be discontinued by late 2017. DKIST first-light operations are planned for 2019, two years after the divestiture of the Sunspot DST. The NSF/AST solicitation also considered the possibility of using some portion of the funding wedge expected for the new CA to cover the expenses of the transition (Item 4 in the RFP). This new CA is due to start on January 1, 2015. We thus face a transition process that extends over almost five years, including a period of three years early in the process (2015–2017) when most of the personnel relocations are occurring. NSO is making an effort to define the transition process, staffing plans, and timeline and has started presenting these plans to the staff at various all-hands meetings. By the end of calendar year 2014, and in preparation for the beginning of the new CA, NSO top-level management would have produced the first draft of the complete process through 2019, with specific emphasis in the first three years (2015–2017).

Table 8.1-1. NSO Transition Risks and Mitigation Strategies					
Risk	Probability (low, medium, high)	Implications	Mitigation		
Losing key staff	1	Delays in transition. Degraded services.	Staffing plan, one-on-one meetings.		
Insufficient budget	\rightarrow	Delays in transition. Descopes of personnel.	Transition budget consolidation and accountability.		
Staff disengagement	\rightarrow	Decreased productivity. Degraded services.	Communications plan. Top- level manager's enhanced role.		
Insufficient project management	¢	Delays in transition. Unreliable budget.	Moving Committee. Hiring new personnel.		
Poor service at key facilities	\rightarrow	Fewer observing days/data products offered to the community.	User's Committee involve- ment. Hiring new personnel.		
DKIST construction delays	\rightarrow	Extended NSO presence in Sunspot.	Relocate budget provisions.		
Sunspot divestiture difficulties	\downarrow	Delays in transition. Budget implications.	Collaborating with interested partners.		

The NSO Director is currently managing the transition. A Moving Committee composed of three employees has been established that provides executive support to the Director. These three members are located in each one of the three most impacted NSO sites: Tucson, Sunspot and Boulder. A Maui-based staff member will eventually join the Moving Committee. Specific duties have been assigned to each of the members of the Moving Committee, in particular:

- Patricia Eliason (Tucson): Lead NSO person for the CU Space Science (SPSC) building 3rd floor renovations. Contact Point with CU Boulder Property Services. Responsible for the inventory of NSO Tucson.
- Geoffrey Roberts (Sunspot): Procurements for the 3rd floor. Responsible for the inventory of NSO Sunspot. Transition budget (together with Rex Hunter).
- Jennifer Ditsler (Boulder): Contact point with LASP. Web pages on the transition. Boulder support.

In addition to these three NSO staff, AURA Central Administrative Services (AURA/CAS) provides support on legal issues such as the Lease for the 3rd floor and numerous other aspects (Memoranda of Understanding, etc.). A Moving Committee e-mail address (*nso_move@nso.edu*) has been created to ensure constant communication among the employees more dedicated to the transition issues. The e-mails are received by the NSO Moving Committee, two AURA/CAS personnel and the NSO Director. This e-mail address is being utilized by all NSO staff to ask

questions about the transition and/or specific needs that staff located in Boulder (or soon to be there) might have. NSO has recently hired Steven Berukoff as the DKIST Data Center Project Manager. Given his broad experience with IT issues, we are in the process of expanding his job description to include NSO-wide interface issues with the CU Office of Information Technology, with which he has already established fluent and efficient communications. Steve Berukoff has been offered a seat on the Boulder Campus Cyberinfrastructure Board (BCCB), an advisory committee to the Vice Chancellor of Research. Steve actively participates in discussions related to IT issues with the Moving Committee.

AURA/HR has started sending a representative to NSO-Boulder on a regular basis. Experience during 2014 has shown that there's an increase in transition activity beginning in early summer when most of the relocations occur and when summer students join the workforce in Boulder. NSO is planning to have an AURA/HR representative in Boulder during the expected peak of transition activity beginning in May 2015.

We currently envisage an NSO in FY19 that has 90 Observatory staff members. Of these, 35 FTEs are expected to be located in Maui (for DKIST operations) and the remaining 55 FTEs in Boulder (including the Directorate, DKIST operations and NISP). The currently envisaged distribution of FTES in the various NSO programs and sites is shown in Figure 8.2-1. The range of FTEs shown for NISP (which relies heavily on outside grant funding) is due to the uncertainties in the funding sources. There also is a range of FTEs for DKIST, as staffing needs are currently being analyzed for DKIST operations to determine more precise FTE requirements.

At the time of this writing (early fall 2014) there are 17 employees in Maui, all of them related to the DKIST construction project and 14 employees in Boulder. The staff in Boulder represents a mixture from DKIST's construction project and NSO's base-funded employees (with a dominance of the former). The administrative personnel in Maui focus on the construction project, including maintaining relations with the National Park Service that are crucial for the daily planning of constructions activities. In Boulder, there is one administrative FTE with shared DKIST construction and NSO transition responsibilities. Because of the urgent need to increase this support, we plan to hire or relocate an additional FTE in Boulder in FY15 (see Section 8.5).

As shown in Figure 8.2-1, the current plan has a total of six FTEs for administrative support in Boulder, including the Business and Assistant Administrators. In Maui, three FTEs will be dedicated to administrative duties. Conversations with AURA/CAS are being maintained to define their presence at the new Boulder and Maui facilities. We currently envisage the presence of one full-time FTE from CAS for contracts and procurements in Maui and one in Boulder. AURA/HR plans to deploy one FTE to Boulder and have a shared FTE with Gemini (Hilo, Hawai'i).

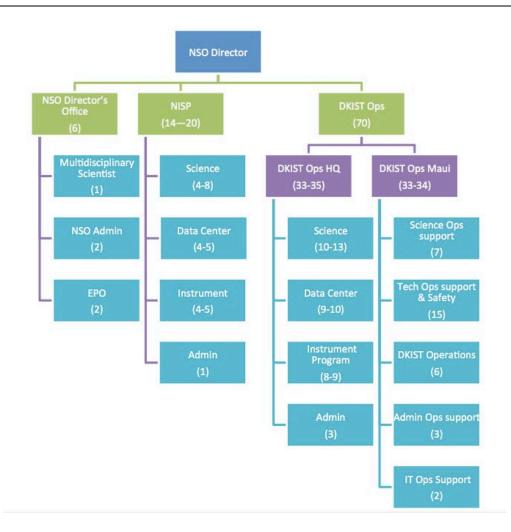


Figure 8.2-1. Expected distribution of FTEs for NSO in FY19. The NSO's Directors office, NISP and DKIST Ops HQ are all Boulder based. This is a tentative diagram that is still being discussed at various levels within the NSO Directorate and the Programs.

8.3 Transition Milestones and Timeline

The AURA Board selected the University of Colorado, Boulder as the site for the new NSO Headquarters. The AURA President and the CU Provost signed a Memorandum of Intent (MoI) establishing the terms of the collaboration between these two institutions, contingent on the approval of DKIST construction and of the new Cooperative Agreement between NSF and AURA for the management of NSO. This MoI was signed in early 2012 and since then, the NSO and CU have been taking steps to strengthen their collaborative ties. CU began offering faculty positions and fellowships with profiles aligned with the broad mission of NSO. CU has filled two such faculty positions over the last two years. In turn, a small contingent of NSO personnel moved to Boulder and into the SPSC building in 2013 to establish a presence on campus. This experience served as a test bed for the collaboration between CU and AURA for the administration of lease agreements, procurements and HR matters and will be valuable as we prepare for major relocations that will formally begin in 2015. Temporary space for offices as well as workstations and lab space are available to the NSO staff on the first floor of the SPSC

building, which also hosts the CU-LASP scientists. The workstations and offices are temporary, but the current lab space occupied by NSO will be permanently used for instrumentation development. In 2014, four additional NSO employees, including the NSO Director and the DKIST Associate Director, relocated to CU-Boulder. Weekly scientific meetings involving LASP, CU Astronomy Department and NSO are convened to foster a closer link between NSO and CU scientists. NSO also participates in the monthly meetings of the Boulder Solar Alliance.

AURA/CAS and CU Research Property Services have prepared a 10-year lease agreement with a start date of January 1, 2015. Signing of this lease will take place only after the NSF has formally vetted the document. The current tenants on the third floor of the SPSC building have been given formal notice of lease termination and are required to leave the building by December 31, 2014. CU has contracted an architectural firm that has worked with NSO on determining what remodeling is needed on the third floor to accommodate our personnel and infrastructure. A 100% Schematic Drawing Proposal based on NSO specifications for the remodeling has been agreed to among all parties involved. The remodeling has been kept to a minimum, but complies with NSO needs, and are well within the budget proposed by CU. CU will conduct a bidding process to select a contractor in the latter quarter of 2014. The SPSC third floor is expected to be ready for NSO occupancy in late spring 2015. At that time, NSO will relinquish the temporary office space currently in use on the first floor.

The NSO relocation thus formally starts with the beginning of the new Cooperative Agreement on January 1, 2015. This is when the first lease payment is scheduled to occur and it represents the first milestone in the relocation. There are three major NSO milestones that impact our transition process (see Figure 8.3-1). These were all mentioned in some form in the NSF solicitation, specifically:

- The NISP budget from NSF/AST should be decreased to \$2M by FY 2016.
- DST and McMP operations should end by 2017.
- DKIST operations are scheduled to start by mid-2019.

The NSO transition is defined to accommodate these three top-level milestones. For example, the staffing plan for NISP has been given priority as they face a severe budget cut relatively soon after the CA formally starts. Our plans are to operate the DST (Sunspot) until 2017 in a manner similar to what has been done in the past. A ramp-down profile of support scientists, observers and technical staff has been defined to accommodate these plans (See Table 8.3-1). The divested resources are transferred to DKIST operations in Boulder and Maui. Similarly, the beginning of DKIST operations in 2019 marks the ramp-up profile for the Maui base and the availability of the Remote Operations Building.

The NISP transition includes another milestone that drives the transfer of resources to CU-Boulder. The SOLIS instrument, traditionally located at Kitt Peak, has been moved recently to the Tucson engineering area for a partial overhaul (including the tunable filter and an upgrade to chromospheric magnetic fields). This process, including the calibration and testing of the upgraded capabilities, is expected to be completed by the end of 2015. After that, relocation to a

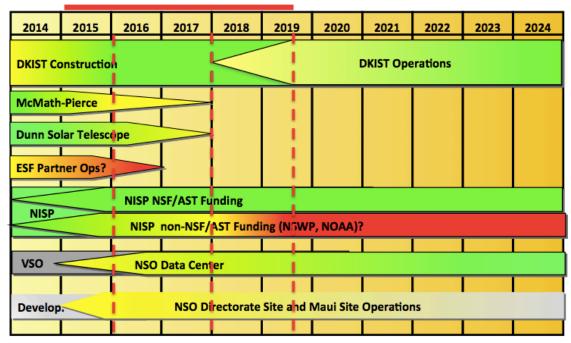


Figure 8.3-1. NSO transition timeline and major milestones (red dashed lines).

Table 8.3-1. Dunn Solar Telescope Personnel Ramp-Down Profile					
Year	Scientists	Observers	Technical	Operations	
2014	3	3	5	Full	
2015	3	3	5	Full	
2016	1	2	4	5 days/week	
2017	1	2	2	5 days/week	

site with superior synoptic properties and offering better coverage of DKIST observations will be sought. We are currently expecting this to happen sometime in 2016. Once relocated to a new site, SOLIS data will flow to the NISP Data Center in Boulder. With SOLIS installed at a new site, the complete engineering team, including the Project Manager, can be relocated to Boulder, ending NISP presence in Tucson.

Table 8.3-2 lists all of the major milestones during the first three years of the Cooperative Agreement and ends with the complete move of NSO HQ to CU Boulder and the ramp up in Maui (although the transition there formally ends in 2019). The approximate time when the events are expected to occur are shown in parenthesis. Most of the personnel relocations are scheduled to take place in the summer, which appears to be the preference of staff based on our experience to date.

		Table 8.3-2. Trans	ition Milestones	
	2014	2015	2016	2017
NSO HQ	 Lease with CU-Boulder signed (Lol). NSB Action Item Director is Boulder - based Sac Peak site leader Transition Plan Draft 	 New CA starts (Q1) Tucson site leader (Q1) Update Transition Plan (Q1) 3rd floor remodeling starts (Q1-2) 3rd floor inauguration (Q2) NSO Tucson moves (Q2-3) NSO Sac Peak moves (Q2-3) 	 Update Transition Plan (Q1) SPD 2016 @ NSO Boulder (Q2) Continue moves from NSO sites (Q2-3) 	 Update Transition Plan (Q1) Continue moves from NSO sites (Q2-3) NSO based funded presence in Sunspot & Tucson ends (Q4)
DKIST	 DCPM hired DKIST AD is Boulder based DKIST staffing plan draft 	 Operations funding wedge (Q1) DC core team formed (Q2) First Science position Maui (Q2-3) WFC team starts relocation (Q2-3) DC PDR (Q4) 	 ROB available (Q2) Support & Operation teams in Maui build up (Q2-3) Continue moves of science team to Boulder/Maui (Q2-3) 	 Support & Operation teams in Maui build up (Q1) DC FDR (Q1) Continue moves to Boulder/Maui (Q2-3) Thermal subsystem, completed (Q3) Telescope mount completed (Q3)
NISP	 NISP staffing plan draft SOLIS relocates to Tucson SOLIS overhaul starts 	 SOLIS RFP announcement (Q1) NISP Scientific staff relocation starts (Q2-3) Relocation of GONG engineering unit starts (Q2-3) NISP AD relocates to Boulder (Q3) 	 NISP DC in Boulder (Q2) SOLIS Relocation (Q4) NISP Scientific staff relocation continues (Q2-3) NISP PM moves to Boulder (Q3) 	NISP is Boulder based

8.4 Transition Budget.

The transition budget includes five components:

- The relocation expenses for personnel who move to Boulder or Maui and for those who decide to retire or leave after using the corresponding accrued vacations.
- The cost of moving equipment and goods to Boulder/Maui.
- The Boulder HQ furniture and IT equipment costs.
- The Boulder HQ lease costs (3rd floor and lab space on the 1st floor).
- The Remote Operations Building (ROB) in Maui and its utilities.

The NSF solicitation explicitly stated that AURA/NSO should address the "...prospects for utilizing a portion of the ATST operations funding wedge, and/or potential savings elsewhere within the budget that might offset the costs of the move." A number of budget entries were provided in the Cooperative Agreement proposal budget (Table 8.4-2) to cover these expenses: the "HQ Development + Relocation" entry, the "HQ Lease and Utilities" entry, and the "ROB Lease" and "ROB Utilities" entries. The last two are related to the potential loan needed to construct the DKIST operations facility in Maui (last bullet above); these are being discussed by AURA/NSO and the NSF elsewhere and will not be addressed here.

The estimate for the cost of the relocations and recruitments (first bullet) has been consolidated thanks to the early moves and hires that NSO has performed over the past two years. The biggest uncertainties come from the staffing plans that are in the process of being elaborated by NSO top-level managers in consultation with the staff. We currently envisage relocating 25

additional existing NSO staff to Boulder and 10 to Maui. Recruitment in Boulder and Maui is expected to reach 15 new hires at both places. With our current estimates from the costs of each one of these relocations and hiring, we have budgeted a total of \$560K for Boulder and \$430K for Maui over the period 2015–2017. The existing staffing plans also assume 25 employees not continuing with NSO and using their accrued vacations for which we have estimated a total cost of \$151K, and 10 severance packages totaling \$222K.

Over the years, NSO has accumulated a wealth of equipment and goods of different nature that need to be relocated to Boulder/Maui (second bullet). The inventories being prepared by the Moving Committee of items at all NSO sites will be used to decide what needs to be moved to the new locations and what can be safely disposed. Among the list of goods that have been identified for relocation, are: Sunspot library, historical archives, optical hardware (including large reference flats and optical tables), IT & AV equipment, furniture and electronic components. The final list of equipment will depend on the future of the facilities and their potential use by the consortia that have expressed interest in them. A total of \$400K has been budgeted for these moves of equipment to Boulder or Maui.

The various items included on the 3rd floor equipment list (third bullet) have been estimated with various degrees of certainty. The furniture is estimated to be \$75K, including \$21K from the current tenants. Remodeling of the main lab on the first floor will need an estimated \$100K as half of the existing space there is being used for offices and will have to be upgraded to standard cleanliness requirements of an optical laboratory. Finally, the IT equipment has been budgeted at \$200K in FY15 (including \$18K in components from the current tenant) as an initial expense (switching and wireless access points) and a maintenance rate of about \$25K a year. Thus, a total of about \$400K has been estimated for equipment for the 3rd floor over a period of three years.

All of these costs slightly exceed \$2M over a three-year period (2015–2017). The corresponding budget can be found in the "HQ Development + Relocation" entry on Table 8.4-2 in the Cooperative Agreement proposal.

The HQ lease costs (fourth bullet) have been established following the original Memorandum of Intent between AURA and CU and can be found in the lease document prepared by AURA/CAS and CU Research Property Services. The cost of the third floor lease steadily rises from \$690K to \$880K over a period of ten years. This amount is augmented by the cost of the laboratory space on the first floor needed for instrumentation development. For FY15, it is expected to cost a total of \$63K. This expense is maintained over the 10-year period of the proposed Cooperative Agreement. In FY15, there is an extra cost (about \$11K) incurred by the fact that NSO is using office space on the first floor while the third floor is being remodeled. The budget line in the CA proposal for the Boulder lease covers all of these expenses with very little margin (a few percent).

8.5 Staffing Plan: Implementation

The CA proposal already disclosed a staffing plan that continues to be our baseline. It can be found in Table 8.3-1 in the proposal. No substantial changes have been made since the submission of the proposal. However, a major effort has been made in defining the details of the process and in communicating these details to the staff. In particular, we identified a clear need to involve all of the NSO staff in the process to understand what their expectations for the transition are. It was clear that there was a subset of our employees who are not willing to relocate to a new site, while others (a majority) were enthusiastically engaged with our future plans. In order to understand what the potential problems could be, a series of one-on-one conversations have been started at the various NSO sites where NSO top-level managers (typically, but not exclusively, members of the Directorate) meet the staff and ask about their future plans and their potential interest in continuing with NSO either in a similar position as the one they already have or in a new position. In these interviews, they are asked about the possibility of joining either one of the two main NSO's programs (DKIST and NISP) and their potential interest to be located in either Boulder or Maui. From these interviews we expect to consolidate a staffing plan (i.e., a list of positions per site, per year with a job description) by the end of calendar year 2014.

DKIST and NISP face different challenges. While the budget for DKIST operations is increasing, the funding from NSF/AST for our synoptic program decreases by half. DKIST operations staffing plan includes positions that in some cases can be naturally filled with existing staff doing similar duties. Other positions, however, are brand new and have no clear equivalent in today's NSO job descriptions—reflecting the intrinsic differences between DKIST operations in Maui and operations at the existing telescopes. The opposite is also true; some of the positions existing plan faces the uncertainties of not knowing what the future funding levels will be. NSO is actively looking for new funding sources to recover a significant fraction of the income lost by the program. In the absence of consolidated revenues, the staffing plan for the synoptic program assumes a worse-case scenario of \$2M base funding allocation and some realistic outside funding in the form of grants following past experiences within the program.

Given this variety of cases, it is clear that implementation of the staffing plan is necessarily complex. To this end, NSO top-level managers in conjunction with AURA/HR have prepared a process for filling the various future positions for NSO operations that includes three different approaches:

<u>Transfer of employees</u>: a future position within the Observatory that has a counterpart within existing Observatory positions with a similar job description. These employees would simply receive a letter communicating a timeframe for their relocation to either Boulder or Maui.

<u>Appointment of employees</u>: a future position that has no similar counterpart within existing Observatory positions, thus requiring a different job description, but an existing employee is known to be qualified for this new role. The Program Director responsible for this job (or the NSO Director) identifies the employee and communicates to the NSO Director their willingness

to appoint the employee to this new position. The NSO Director evaluates the case and decides on the adequacy of the nomination and notifies the Program Director of his decision. HR is consulted about the acceptability of the candidate given his/her qualifications and past Performance Evaluations.

<u>Applications process</u>: a future position is identified for which no existing employee exists, or more than one employee are identified. A position is open and a regular hiring process is started. These positions will be internally advertised for NSO employees for a period of five days. If the Hiring Committee identifies no suitable internal candidate, the position is externally advertised.

For FY15, NSO is planning to fill through the above processes the following positions (contingent on the approval of the requested budget):

- 1 Administrative Assistant. Boulder-based. Application.
- 2 Education and Public Outreach positions. Boulder/Maui-based. Application.
- 1 IT support position. Boulder-based. Appointment or application.
- 4–6 DKIST Data Center positions. Boulder-based. Appointments and applications.
- 1 DKIST operations software tools. Boulder-based. Appointment or application.
- 1 Scientist position. Maui-based. Appointment or application.
- 0–1 Support operations position. Maui-based. Appointment or application.

Job descriptions for these positions are being made available through the intranet Web site as they become available.

8.6 Relocation Policy

A relocation policy was prepared by the NSO top-level managers using market studies prepared by HR and the budget projections presented in the CA proposal. Proposed salary increases for Boulder are an average of 8%, with a gradual scale ranging from 15% for the lowest salaries to 0% for the highest ones. The policy can be downloaded from the following password-protected link:

http://www.nso.edu/sites/www.nso.edu/files/files/boulder/NSO-HQ%20Relocation%20Policy%20Revised%203-14.pdf

8.7 Communications and Staff Feedback

Ensuring the continued mission of the Observatory during the transition requires keeping the NSO staff apprised of the relocation developments throughout the process. Uncertainty about the future will necessarily complicate retention of key staff and might prevent the Observatory from adequately serving the community as the primary provider of key ground-based solar facilities. An additional complication stems from the fact that NSO is currently distributed at four different sites: Tucson, Sunspot, Boulder and Maui. Frequent and fluent communication among all sites and an understanding of issues such as staff morale are mandatory for a successful transition process.

Thus a strategy has been prepared to ensure effective communication between NSO's programs, among the different sites, and with the staff. Its key components are:

- Regular bi-weekly Directorate meetings of top-level NSO managers. The list of topics to be discussed at the meeting and the minutes are distributed to the staff and posted on the NSO intranet.
- Periodic all-hands meetings where the status of the transition is revised and input requested of the staff. The first such all-hands meetings was in July 2014 and another is expected to occur in this calendar year.
- A transition Web site accessible through the NSO intranet, where news about the transition process are regularly posted. The (password protected) Web site can be accessed at *http://www.nso.edu/relocation*. An FAQ Web page on the transition is available on the transition Web site. Currently there are 28 questions and answers listed.
- Included in this transition Web site is a staff feedback page where NSO staff can submit questions about the relocation (see Figure 8.7-1). These submissions can be anonymous if desired. Over the last three months, a total of 11 questions have been received through this feedback mechanism. Most of the time, these questions have demanded a new entry on the FAQ site. Updates to the FAQ list are regularly announced to the entire staff.
- Nomination of Site Leaders that are single points of contact with the NSO Director for any development that might require his intervention. In Sunspot, the DST scientist, Han Uitenbroek, has been appointed as Sunspot Site Leader. In Tucson, the current Deputy Director, Mark Giampapa, will transfer with the start of the new Cooperative Agreement to the position of Tucson Site Leader. The duties of the Site Leaders are primarily to keep the NSO Director informed of any issues that they might consider relevant and act as NSO liaison with future partners interested in developing activities at either site. Potential stakeholders for the Sunspot site are the New Mexico State University and the Southern Rockies Education Centers (Texas). For Tucson, the AURA-led institutions, NOAO, LSST and the Tohono O'odham Nation are potential partners.

In addition to these strategy components, the NSO Director makes regular visits to all three sites and maintains fluent communications with the top-level managers at each site.

A Transition Plan document is being drafted that will include all of the components of the transition, including the staffing plans, and will be regularly maintained as the process evolves. This document will be presented to the AURA Solar Observatory Council for review.

ATIONAL SOLAR	DBSERVATORY Kitt Peak Sacramento Peak DKIST NISP VS
	Relocation Feedback
Search	Name (Onking)
Construction of the second sec	Name (Optional)
Our Mission	Your name, if you wish to include it. You may remain anonymous as well; no other identifying information will
 Current Images Work at NSO 	be included with your comment.
Telescope Facilities	be included with your comment.
Major Projects	Comment
 Observing 	
Press	
Publications	
• Visiting	
 Information 	
 Digital Library 	Please share any feedback you have about the NSO Directorate relocation to Boulder, CO.
 Education & 	
Outreach	Submit
• FTP	Submitted by wwwnso on Fri, 06/27/2014 - 11:10
 Log In 	

Figure 8.7-1. Relocation feedback available through the NSO intranet Web pages for the staff to ask any question related to transition issues.

9 FY 2015 SPENDING PLAN

The NSO spending plan is based on receiving the President's FY 2015 budget request of \$13M for NSO.

9.1 Total Budget

Table 9.1-1 summarizes the funding that NSO expects to receive as new NSF funding, as well as anticipated non-grant revenues for support of operations in FY 2015. The NSO program in FY 2015 was developed based on receiving \$8,000K of NSF funding for the NSO base program and an additional \$5,000K as a funding wedge for ramping-up DKIST operations. NSO receives additional operational support from the Air Force Research Laboratory (AFRL) through an MOU between the Air Force and NSF, in exchange for supporting several AFRL staff at NSO/Sac Peak. The Air Force Weather Agency (AFWA) has restored their support to NSO at its original level of \$800K in FY 2015. It is unclear whether this contribution will be maintained next year. NSO also earns revenue from cafeteria, Visitor Center, and housing operations on Sacramento Peak that are used to support the respective functions.

Table 9.1-1 NSO FY 2015 Funding	
(Dollars in Thousands)	
NSF Astronomy Division Funding	\$13,000
AFRL Support for Sac Peak Operations	352
AFWA Support for GONG Operations	800
Revenue (Housing, Kitchen, Visitor Center)	176
McMP NASA/GSFC Support	17
Programmed Indirects/Carryover	-
Total NSO Funding	\$14,345

In addition to the funds shown in Table 9.1-1, NSO receives funding through a variety of grants and contracts with both NSO and non-NSO principal investigators. These funds are used to hire research fellows for specific programs, support visiting PIs and students, and to enhance capabilities needed for these programs. The enhanced capabilities are then normally made available to the user community.

The funding shown in Table 9.1-1 is allocated to the various programs NSO conducts to fulfill its mission. Table 9.1-2 shows the program areas in which funds will be expended, and those are broken down further into the work packages within each funding area (telescope operations, instrumentation, administration, EPO, etc.). The table also shows how we apply the revenue and some of our indirect cost earnings to cover expenses not supported by the NSF FY 2015 funding. Funding that NSO provides AURA for business support has been allocated to the Director's Office program. These funds are transferred to AURA for the Corporate Office fee, HR, CAS procurement, and contracting services in Tucson.

The Scientific Support/Computing line item has different meaning for different programs. While for DKIST and NISP it represents the budgets for their respective Data Centers, for Tucson it includes a payment to NOAO CCS IT service. For Sunspot it includes the local IT support and the library. Something similar happens with the Support/Maintenance/Development entry. For DKIST, it represents funding for developing instrumentation not included in the construction project (such as MCAO), whereas for Sunspot it represents maintenance of the DST. NISP uses the corresponding funding for the maintenance of GONG and SOLIS including its ongoing upgrade. For the McMP a minimum budget is allocated (same as last year) that cannot cover any malfunction of the telescope. In case any problem occurs that prevents the proper use of the telescope, the Observatory uses reserves to solve the malfunction after a careful cost analysis.

Table 9.1-2 NSO Spending Plan							
(Dollars in Thousands)							
Expenses	Director's Office	DKIST	NISP	Tucson & NOAO	Sunspot	TOTAL	
Director, Staff, Committee Support	709					709	
Directorate Site Development	797					797	
Scientific Staff		684	1060	181	477	2,402	
Scientific Support/Computing		1133	1159	227	270	2,789	
Telescope Support/Maint./Develop.		391	969	3	564	1,927	
Telescope Operations		180	519	88	340	1126	
Facilities	825	1034		180	721	2760	
Administrative Support & NOAO		140	63	80	212	495	
Education & Public Outreach	280			40		320	
Recruitment & Insurance	125					125	
DKIST Fellow		141				141	
AURA Management Fee & Support	68	148	265	18	255	754	
Program Total	\$2,804	\$3,852	\$4,035	\$817	\$2,838	\$14,345	
Revenue						_	
Programmed Indirects/Carryover						0	
Housing Revenue					-104	-104	
Meal Revenue					-17	-17	
NSF REU/RET Funding						0	
Air Force Support			-800		-352	-1152	
McMP NASA/GSFC Support				-17		-17	
Visitor Center Revenue					-55	-55	
NSF/AST Funds	\$2,804	\$3,852	\$3,235	\$800	\$2,310	\$13,000	

9.2 Work Package Break Out

Tables 9.2-1 to 9.2-6 show the spending plan for the major functional areas in more detail, breaking out payroll and non-payroll by work packages.

9.2.1 Director's Office

Table 9.2-1 presents the Director's Office budget. Staff included in the Director's office budget are the Director, 0.5 of the Tucson Site Leader's salary, an Executive Administrative Manager (in Tucson), 0.5 of an administrative staff in Boulder, 1 IT support staff in Boulder, 0.5 of an administrative staff helping with relocation issues and two EPO personnel. The other half of the Tucson Site Leader's salary is included in the Tucson budget. Non-payroll expenses include travel, supplies and materials, and other miscellaneous expenses incurred by the Director.

The HQ Lease is used to cover the expenses of all of the space used by NSO at the SPSC building on the East campus of CU-Boulder. The HQ Development budget line has been explained in Section 8.4.

NSO plans to ramp down our historical collaboration on EPO with NOAO and establish our own outreach program for which we are planning to hire two personnel in FY 2015. It is expected that one EPO position will be located in Boulder (NSO-wide EPO) and the other in Maui (participating in the local community in Maui including schools).

Table 9.2-1 Director's Office							
(Dollars in Thousands)							
	FTEs	Payroll	Non-Payroll	Total			
Staff	4	622	87	709			
HQ Lease			825	825			
HQ Development	0.5	58	739	797			
NSO Outreach (EPO)	2	220	60	280			
Total Director's Office	6.5	\$901	\$1,711	\$2,612			

The Director's Office will utilize funds from the \$5M funding wedge that NSO expects to receive in FY 2015. The first use appears in the two HQ lines that amount to \$1622K. The outreach line is not entirely new and a small fraction is coming from the reduced NOAO EPO contribution and from the summer program in Sunspot (that will be maintained, but instead of appearing in the Sunspot budget, it has been allocated to EPO in the Director's Office). The new funds used for the NSO EPO program are \$220K. On the staff line, about \$100K in payroll is used to support administrative positions in Boulder. Thus, strictly speaking, slightly less than \$2M is being allocated to the Director's Office and not to the DKIST Operations budget (next section).

9.2.2 DKIST Operations Program

The DKIST Operations Program is under the direction of Thomas Rimmele as DKIST Associate Director.

This is the first NSO Annual Program Plan where a specific budget allocation for DKIST Operations appears. In the past, efforts to ramp up DKIST Operations have been done through resources based mostly in Sunspot and from the Observatory reserves. The total budget allocated for DKIST Operations in FY 2015 amounts to \$3.7M out of which \$3M corresponds to the new funding wedge and the rest to existing resources of the Observatory that have been reallocated to this program (mostly personnel). Table 9.2-2 describes the DKIST Operations budget for FY 2015 in some detail.

Table 9.2-2 DKIST Operations Program						
(Dollars in Thousands)						
	FTEs	Payroll	Non-Payroll	Total		
DKIST Scientific Staff	3.20	400	94	494		
DKIST Fellow	1.00	120	21	141		
Operations Support Science Staff	1.00	150	40	190		
Operations	1.00	140	40	180		
Administrative Services	1.00	110	30	140		
Data Center/Software/Computing	5.00	728	405	1133		
Instrumentation Program/Maintenance	2.00	280	111	391		
ROB Lease			884	884		
ROB Utilities/Taxes/Insurance			150	150		
Total NSO/DKIST	14.2	\$1,929	\$1,775	\$3,704		

All aspects of operations are being ramped up this year in both Boulder and Maui. A significant effort corresponds to the DKIST Data Center that is planning to hire (or transfer from other NSO programs) at least four new personnel and start acquiring equipment (workstations, network equipment, storage hardware, network security appliances, etc.).

9.2.3 NSO Integrated Synoptic Program (NISP)

The NSO Integrated Synoptic Program combines staff from SOLIS and GONG under the direction of Frank Hill as Associate Director. NISP suffers a reduction of 4 FTEs and of slightly less than \$800K in the NSF/AST contribution as compared to the same estimates in FY 2014. NISP budget can be found in Table 9.2-3.

Table 9.2-3 NISP Program						
(Dollars in Thousands)						
	FTEs	Payroll	Non-Payroll	Total		
Scientific Staff	7.50	912	148	1060		
Sci. Support/Computing	7.90	753	406	1159		
Instrument Development	4.00	450	519	969		
Telescope Operations	5.00	339	180	519		
Administrative Services	1.00	63	0	63		
Total NSO/NISP	25.40	\$2,517	\$1,253	\$3,770		

NISP is broken down into an Atmospheric section and an Interior section, each led by a program scientist reporting to the NISP Associate Director. The Telescope Support/Maintenance/-

Development staff are supervised by a Program Manager and support both SOLIS and GONG instruments and upgrades as required. The science staff support the various data products produced by NISP and respond to the community's need for new products. Both SOLIS and GONG data are reduced daily and added to the NSO Digital Library, where the solar community can download them.

9.2.4 Tucson/McMP

Table 9.2-4 shows the budget breakdown for Tucson and support for the McMath-Pierce Solar Telescope (McMP) facility.

The Tucson/McMP staff provide support for operations on Kitt Peak and for operations of the McMath-Pierce Solar Telescope. The scientific personnel corresponds to 0.5 FTE of the Tucson Site Leader and 0.5 FTE of a tenured scientist shared with DKIST Operations. The McMath observing support has been reduced to 0.75 FTE following the recommendation in the letter of the Division Director of the NSF/AST to the McMP Consortium (dated May 31, 2013).

Table 9.2-4 NSO/Tucson/McMP						
(Dollars in Thousands)						
	FTEs	Payroll	Non-Payroll	Total		
Scientific Staff	1.00	168	13	181		
Software Support/Computing	0.00		7	7		
Instrument Development	0.00		3	3		
Telescope Operations	0.75	65	23	88		
Utilities on Kitt Peak	0.00		55	55		
Total NSO/Tucson	1.8	\$233	\$101	\$334		

With the relocation of SOLIS to the Tucson farm, the cost of utilities on Kitt Peak (traditionally at \$80K) has been reduced in FY15 to \$55K. The reduction corresponds to the cost of the SOLIS data bandwidth.

9.2.5 Sacramento Peak

Compared to FY 2014, the Sacramento Peak has 6.5 FTEs fewer and a cost to the NSF/AST that is \$450K smaller. The budget breakdown is presented in Table 9.2-5.

Table 9.2-5 NSO/Sacramento Peak						
(Dollars in Thousands)						
	FTEs	Payroll	Non-Payroll	Total		
Scientific Staff	3.50	447	30	477		
Scientific Support/Computing	2.00	182	88	270		
Instrument Development	5.00	512	52	564		
Telescope Operations	4.00	314	26	340		
Facilities	6.00	295	364	659		
Administrative Services	3.50	192	20	212		
Visitor's Center	0.50	30	32	62		
Total NSO/Sacramento Peak	24.50	\$1,970	\$613	\$2,583		

NSO/SP scientific staff support the Dunn Solar Telescope and participate in development of DKIST operations. The DST Program Scientist oversees telescope operations and projects and supervises the NSO/SP Technical and Telescope Operations Manager, IT support, and the DST chief observer. The scientists also support the TAC process and observatory operations (library, outreach, instrument program, modeling, and users).

The Telescope Support/Maintenance/Development staff support DST maintenance and operations and upgrades to the DST control system and focal-plane instrumentation so users can take full advantage of diffraction-limited imaging. The DST is also serving as a test bed for DKIST by exploring ways to operate several instruments simultaneously. Telescope staff operate the DST, provide user support, help with instrumentation installation and interfaces, and perform maintenance tasks on the telescope. In FY 2015 regular telescope operations as in the past are planned.

The Sac Peak administrative staff oversee general site maintenance and daily site operations, logistical visitor support, purchasing, shipping, receiving, and budgeting. The facilities budget includes costs for buildings (offices, shops, civil engineering facilities, and administrative facilities), grounds, maintenance, utilities, housing (funding for housing support comes from rental revenue), water and sewage treatment, site snow removal and road maintenance.

9.2.6 AURA Fees and NOAO Support

Table 9.2-6 discloses the expenses NSO incurs in Tucson. NOAO payments include support for EPO at a level of \$40K (reduced by a similar amount compared to FY 2014), NOAO IT Support at \$220K (reduction of \$30K) and the NOAO Photo Labs support contributions that stays the same as in FY 2014. A facilities use fee of \$125K is allocated for the office and laboratory space in Tucson.

Table 9.2-6 AURA & NOAO Sup	port
(Dollars in Thousands)	
	Total
NOAO EPO Support	40
NOAO CCS Support	220
NOAO Photo Labs	80
Insurance	75
Recruitment	50
AURA Management Fee	386
AURA CAS & HR Fee	368
Facilities Use Fee	125
Total NSO/Tucson	\$1,344

AURA central services fee includes support for the Director and the Programs covering HR issues and accounting and procurement in all NSO sites. The AURA Management Fee is \$126K higher than the corresponding one in FY 2014 due to the increased budget.

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APPENDICES

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APPENDIX I. ACRONYM GLOSSARY

APPENDIX A. NATIONAL SOLAR OBSERVATORY 2020–2025 VISION¹

NSO will support and lead community research into the nature of the Sun by providing critical groundbased optical capabilities. The Sun is the archetypal astrophysical body, and we can exploit its proximity to explore fundamental processes not directly observable elsewhere in the Universe. Perhaps more importantly, the Sun is the source of the highly variable heliosphere in which the Earth and humanity reside. NSO's unique facilities will include the world's largest solar telescope and a network of full-Sun imaging magnetometers to continuously observe the Sun's structure and evolution. A resident scientific staff will support the development and exploitation of these facilities, support a diverse community of users, and point the way to mid-century frontiers.

The NSO 2020 – 2025 vision provides critical capabilities for solar research that address both fundamental science issues and vital societal imperatives enunciated in several decadal surveys – *New Worlds, New Horizons in Astronomy and Astrophysics,* and *The Sun to the Earth and Beyond* (and its successor *Solar and Space Physics Decadal Survey* to be released in Spring 2012) – as well as the recent NSF sponsored *Workshop on the Future of Ground-based Solar Physic.* The NSO science vision is focused on the basic question¹ of how the Sun creates and evolves its magnetic field: to understand the fundamental physics and its manifestations in other astrophysical settings, and how this violent activity impacts the solar system and Earth while also helping to shield humanity from dangerous galactic cosmic particles. The NSO vision of societal benefits and impacts centers on research leading to a predictive capability for variations of the Sun's radiative and eruptive outputs and planetary effects². The NSO vision is founded upon community-based research objectives and requirements, and enables effective responses to new discoveries, synergistic research with planned and future space missions, and testing the results of advanced numerical models of solar phenomena.

To achieve this vision for the solar research community, NSO is replacing its 50+ year old facilities with major new observational capabilities. The range of observational capabilities that will be available in 2020 – 2025 includes world-leading high-resolution observations of the vector magnetic field, thermal and dynamic structure of the solar surface and atmosphere, and measurements of structure and dynamics of the solar interior, both for short-term and solar-cycle-long time periods. These capabilities will be provided by the high-resolution *Daniel K. Inouye Solar Telescope (DKIST)* (formerly the *Advanced Technology Solar Telescope* (ATST)) and moderate-resolution, nearly continuous ("synoptic") observations of the full solar disk through the *NSO Integrated Synoptic Program* (NISP).

NSO in 2020 and beyond will enable the community to:

1. Clearly resolve fundamental magnetic structure and processes in space and time, and achieve high photon flux for accurate, precise measurements of physical parameters throughout the solar atmosphere⁴;

⁴ NWHH, p. 64

¹See NSO 2012-2016 Long Range Plan for science goals (*http://www.nso.edu/reports*) ²NWNH, p. 64

³ NWHH, pp. 29, 37,38, 60,61, 115

- 2. Study the drivers and manifestations of the long-term, quasi-cyclic, inhomogeneous and intermittent solar magnetic fields and flows;
- 3. Resolve outstanding uncertainties in the abundance of atomic species;
- 4. Understand space weather and climate as they affect Earth, the solar system, and space assets today⁵, and as a pathfinder for the study of exo-planet habitability;
- 5. Prepare the next diverse generation of solar researchers; and,
- 6. Carry out coordinated investigations with solar space-based missions using NSO's robust and adaptable capabilities.

To achieve this, the NSO will in priority order:

- 1. Operate and enhance the DKIST, currently under development; and
- 2. Operate and enhance the multi-site NISP

To continue NSO's engagement in education and outreach NSO will6:

- 1. Conduct a vigorous training program for undergraduate, graduate, thesis students, and postdoctoral fellows;
- 2. Provide research experience and science training for middle school and high school teachers;
- 3. Conduct public outreach through its visitor center, tours, classroom talks and displays; and,
- 4. Increase its efforts to establishing a more diverse NSO staff and bringing underrepresented minorities into science and engineering in general.

Failure to build DKIST or a serious delay in its construction would create a significant gap in US solar astronomy. We would lose the capability to probe the physics of solar magnetic fields on spatial and temporal scales that are critical (according to both theory and observation) for understanding the energy balance of the Sun (and stars) and solar activity that impacts Earth. While space missions provide a complementary part of the required capability, a permanent space-borne 4m class telescope with the necessary functionality and flexibility is not affordable.

⁵ NWNH, p. 29: Serving the Nation

⁶ NWNH, Chapter 4

APPENDIX B: OBSERVING AND USER STATISTICS (OCTOBER 1, 2013 - SEPTEMBER 30, 2014)

In the 12 months ended 30 September 2014, 65 observing programs, which included 8 thesis programs, were carried out at NSO. Associated with these programs were 62 scientists, students and technical staff from 35 US and foreign institutions.

NSO Observing Programs by Type (US and Foreign)		
12 Months Ended September 2014	Nbr	% Total
Programs (US)	50	77%
Programs (non-US)	7	11%
Thesis (US, involving 6 grad students)	5	8%
Thesis (non-US, involving 5 grad students)	3	5%
Total Number of Unique Science Projects*	65	100%

*Includes observing programs conducted by AURA staff scientists.

Users of NSO Facilities by Category					
	Visitors AURA S				AURA Staff
	US	Non-US	Total	% Total	
PhDs	31	18	49	79%	16
Graduate Students	6	5	11	18%	0
Undergraduate Students	0	0	0	0%	0
Other	2	0	2	3%	10
Total Users	39	23	62	100%	26

Institutions Represented by Visiting Users**					
	US	Non-US	Total	% Total	
Academic	12	11	23	66%	
Non-Academic	9	3	12	34%	
Total Academic & Non-Academic	21	14	35	100%	

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

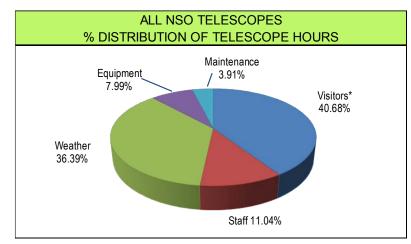
Number of Users by Nationality				
Australia	1	Mexico	1	
Belgium	1	Scotland, UK	1	
Germany	6	Spain	1	
Ireland, UK	8	Brazil	1	
Italy	3	United States	65	

Institutions Represented by Users				
Foreign Institutions (14)				
Armagh Observatory, Ireland, UK				
Belgian Institute for Space Aeronomy, Belgium				
INAF - Arcetri Astrophysical Observatory, Italy				
Instituto de Astrofísica de Canarias, Spain				
Kiepenheuer Institute, University of Freiburg, Germany				
Max Planck Institute for Solar System Research, Germany				
Monash University, Australia				
National Institute for Space Research, Brazil				
Queen's University, Ireland, UK				
Universidad de Monterrey, Mexico				
University of Florence, Italy				
University of Glasgow, Scotland, UK				
University of Koeln, Germany				
University of Rome "Tor Vergata", Italy				
US Institutions (21)				
California State University, Northridge				
California Institute of Technology				
California Polytechnic State University				
Dickinson College				
Johns Hopkins University				
New Jersey Institute of Technology				
New Mexico State University				
University of Arizona				
University of Kansas				
University of Hawaii, IFA				
University of Texas-Austin, McDonald Observatory				
University of Wisconsin, Madison				
Brilliant Sky Observatory, Arizona				
High Altitude Observatory, NCAR, Boulder				
Lockheed Martin Solar & Astrophysics Lab				
Lowell Observatory				
NASA/Ames Research Center				
NASA/Goddard Space Flight Center (NASA/GSFC)				
Planetary Science Institute (PSI)				
PlanetWave Instruments, California				
US Air Force/Philips Lab (USAF/PL/GSS)				

FY 2014 USER STATISTICS – TELESCOPE USAGE & PERFORMANCE DATA

In the fiscal year ended 30 September 2014, 40.7% of the total available telescope hours at NSO/Sacramento Peak and NSO/Kitt Peak went to the observing programs of visiting principal investigators; 11.0% were devoted to those of NSO scientists. Scheduled maintenance (including instrument tests, engineering, and equipment changes) accounted for 3.9% of total allotted telescope hours.

Total "downtime" (hours lost to weather and equipment problems) for NSO telescopes was 44.4%. A significant portion of these lost observing hours were due to bad weather (36.4%), with 8.0% lost to equipment problems.



*Includes synoptic/archival data made immediately available to scientific community at large.

NSO TELESCOPES Percent Distribution of Telescope Hours (Scheduled vs. Downtime) 01 October 2013 - 30 September 2014						
% Hours Used By: % Hours Lost To: % Hrs. L				% Hrs. Lost To:		
Telescope	Hours Scheduled	Visitors ^a Staff Weather Equipment		Scheduled Maintenance		
Dunn Solar Telescope/SP	3,634.0	27.6%	13.3%	40.4%	4.2%	14.6%
McMath-Pierce*	3,144.0	24.6%	32.3%	32.7%	10.4%	0.0%
KP SOLIS Tower ^{a,b}	5,188.7	62.8%	0.0%	26.2%	11.0%	0.0%
FTS Lab ^c *	0.0	0.0%	0.0%	0.0%	0.0%	0.0%
Evans Solar Facility	1,605.0	30.4%	0.0%	67.5%	2.1%	0.0%
Hilltop Dome	0.0	0.0%	0.0%	0.0%	0.0%	0.0%
All Telescopes	All Telescopes 13,571.7 40.7% 11.0% 36.4% 8.0% 3.9%					

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

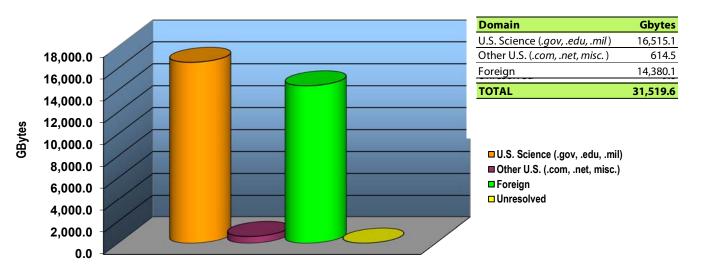
^bFormerly the Kitt Peak Vacuum Telescope (KPVT).

^cDuring FY12, the FTS was moved out of the McMath-Pierce Facility and to a university campus.

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

FY 2014 USER STATISTICS – ARCHIVES & DATA BASES (October 1, 2013 - September 30, 2014)

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



DATA (Gbytes) DOWNLOADED FROM NSO FTP & WWW SITES 01 October 2013 - 30 September 2014

PRODUCT DISTRIBUTION BY DOWNLOADED GBYTES 01 October 2013 - 30 September 2014

Site	Product Type	Gbytes	%
Т	NISP/GONG Helioseismology	11,816.58	36.256%
SP & T	Other	9,058.61	27.794%
Т	NISP/GONG (Magnetograms, spectra, time series, frequencies)	8,495.94	26.068%
Т	NISP/GONG H-alpha	2,796.16	8.579%
Т	NISP/SOLIS (VSM, ISS, FDP)	285.24	0.875%
Т	KPVT (magnetograms, synoptic maps, helium images)	63.37	0.194%
SP	Staff Pages	26.60	0.082%
SP	Press Releases	22.15	0.068%
SP	General Information	16.03	0.049%
Т	FTS (Spectral atlases, general archive)	9.40	0.029%
SP	DST Service Mode Support	1.53	0.005%
SP	SMEI Experiment & Data Pages	0.07	0.000%
Т	Evans/SP Spectroheliograms (Hα, Calcium K images)	0.01	0.000%
SP	Icon & Background Images	0.00	0.000%
TOTAL		32,591.68	100.000%

APPENDIX C: ORGANIZATIONAL PARTNERSHIPS

C1. 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 work closely with the solar community and provide leadership to strengthen solar research, renew solar facilities and to develop the next generation of solar instrumentation. Examples of NSO meeting this responsibility include the addition of rapid magnetograms and H α images to GONG; development of solar adaptive optics and multi-conjugate adaptive optics for both NSO and university telescopes; development of infrared observing capabilities in collaboration with the University of Hawai'i, California State University-Northridge, New Jersey Institute of Technology and NASA; leading the development of SPINOR in collaboration with HAO, and participating in IBIS with Arcetri Observatory, and ROSA with Queen's University Belfast. Table C.1 lists ongoing joint projects and development efforts.

NSO will continue to work closely with the DKIST Science Working Group and the community to develop a sound operations plan for exploiting the full potential of the DKIST.

Table C.1. Joint Development Efforts				
Telescope/Instrument/Project	Collaborators			
Daniel K. Inouye Solar Telescope (DKIST)	HAO, U. Hawai'i, U. Chicago, NJIT, Montana State U., Princeton U., Harvard/Smithsonian CfA, UC-San Diego, UCLA, U. Colorado, NASA/GSFC, NASA/MSFC, Caltech, Michigan State U., U. Rochester, Stanford U., Lockheed-Martin, Southwest Research Institute, NorthWest Research Associates, Cal State Northridge			
Adaptive Optics, Multi-Conjugate AO	NJIT, Kiepenheuer Institute, AFRL			
Diffraction-Limited Spectro-Polarimeter ((DLSP)	НАО			
Spectropolarimeter for Infrared and Optical Regions (SPINOR)	HAO			
Rapid Oscillations in the Solar Atmosphere (ROSA) Instrument	Queen's University, Belfast			
Narrowband Filters and Polarimeters	Arcetri Observatory, Kiepenheuer Institute			
Synoptic Solar Measurements	USAF/AFRL, NASA			
IR Spectrograph and Cameras	U. Hawai'i, Cal State Northridge, NJIT			
Advanced Image Slicer & Integral Field Unit	Cal State Northridge			
Virtual Solar Observatory	NASA, Stanford, Montana State, Harvard-SAO			
H-alpha Imaging System (GONG)	Air Force Weather Agency (AFWA)/AFRL			

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

C2. Operational Partnerships

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

The NSO hopes to continue its long-standing relationship with the US Air Force space science group into the DKIST era. The AF has been contributing to the DKIST project through their mirror coating chamber and are looking for ways to support DKIST detector development. Currently, NSO is vigorously pursuing other partnerships. It has had discussions with many organizations and has received letters of intent from several institutions to support DKIST. These include organizations in Germany; the United Kingdom; a consortium of the Netherlands, Sweden, and Norway; and the US Air Force. Other potential partnerships include Italy, Japan, Spain, and Canada. Scientists from Italy, Japan, and Spain are currently involved on the DKIST Science Working Group. NSO has formed a close working relationship with the University of Hawai'i for DKIST operations and expects other partners to have some involvement in operations as well.

	Table C.2. Current NSO Partnerships
Partner	Program
Air Force Research Laboratory	 Solar activity research at NSO/SP; telescope operations; adaptive optics; instrument development; 2 scientists, including 1 postdoc, stationed at NSO/SP; daily coronal emission line measurements; provides operational funding for SP: \$400K-Base and various amounts for instrument development. NSO/Tucson Farside ADAPT Project support (0.25 FTE).
Air Force Weather Agency	Funded the addition of an H-alpha capability for GONG. Providing \$740K in FY15 for GONG/Synoptic Program operations.
NASA	 McMath-Pierce: 0.2 FTE observing support in FY14; Solar-Stellar Research; Planetary Research observations science planning, mission operations, data analysis) (via Lockheed-Martin sub-award). GONG: 3.0 FTE Scientific Support; SDO/HMI Pipeline Development Support (0.7 FTE) Virtual Solar Observatory Development Support (0.75 FTE). SHINE research support for 3 scientists at 0.17 FTE each. Active Region Flaring Predictions using Helioseismology research support via CU-Boulder sub-award (0.33 FTE).
	Boulder sub-award (0.33 FTE).

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

APPENDIX D: PUBLICATIONS (OCTOBER 2013 THROUGH SEPTEMBER 2014)

Author-NSO StaffAuthor-REUAuthor-RETAuthor-Grad StudentAuthor-Non-REU Undergrad

The following is a partial list of papers published during October 2013 through September 2014 by NSO staff, as well as papers resulting from the use of NSO facilities.

Refereed Publications

- 1) Altrock, R. C., "Forecasting the Maxima of Solar Cycle 24 with Coronal Fe XIV Emission", *SoPh* 289(2), 02/2014.
- 2) Arsensio-Ramos, A., "A meta-analysis of the magnetic line broadening in the solar atmosphere", A&A 563: A114, 03/2014.
- 3) Baldner, C. S., Basu, S., Bogart, R. S., Burtseva, O., González Hernández, I., Haber, D. A., Hill, F., Howe, R., Jain, K., Komm, R. W., et al., "Latest Results Found with Ring-Diagram Analysis", SoPh 287: 57-69, 10/2013.
- 4) Balthasar, H., **Beck, C. A. R.**, Louis, R.E., Verma, M., and Denker, C., "Near-infrared spectropolarimetry of a δ-spot", *A&A* **562**: L6-, 02/2014.
- 5) Barnes, G., Birch, A. C., Leka, K. D., and Braun, D. C., "Helioseismology of Pre-emerging Active Regions. III. Statistical Analysis", *ApJ* **786**(1): 19, 05/2014.
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- 13) **Criscuoli, S.**, and **Uitenbroek, H.**, "Interpretation of Solar Irradiance Monitor Measurements through Analysis of 3D MHD Simulations", *ApJ* **788**: 151-156, 06/2014.
- 14) **Criscuoli, S.**, "Comparison of Physical Properties of Quiet and Active Regions Through the Analysis of MHD Simulations of the Solar Photosphere", *ApJ* **778**(1): 27, 11/2013.
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Conference Proceedings and Other Publications

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APPENDIX E: MILESTONES FY 2015

This section describes the major project milestones for 2015.

E1. Daniel K. Inouye Solar Telescope (DKIST)

- M1 Final Blank Polishing Acceptance
- M1 Cell Assembly Factory Acceptance Testing
- Top End Optical Assembly Factory Acceptance Testing
- Coude Optics Contract Award
- Start of Enclosure Site Assembly
- TMA Mount Factory Acceptance Testing
- Start Site TMA Coudé Install
- Instrument CDRs
 - DL-NIRSP CDR
 - ViSP CDR
 - VTF CDR
- System Reviews The remaining sub-system design reviews are:
- High Level Software Systems FDR
- ◆ DL-NIRSP CDR
- PA&C FDR
- WFC FDR
- Boulder Relocation of WFC Team

E2. Daniel K. Inouye Solar Telescope – Operations Ramp Up

The Operations ramp-up phase includes: the development of DKIST operations procedures; development of all necessary tools to manage proposal submission, review proposals and support time allocation; development of tools software to generate, schedule, track and conduct observations; the development of the DKIST Data Center; and 2nd generation instrumentation such as multi-conjugate adaptive optics (MCAO).

- Recruit support science staff in Boulder and Maui.
- Further develop DKIST service mode and engage community.
 - Conduct 1-2 service mode observing campaigns at DST.
 - Disseminate service mode data via NISP Data Center.

- Produce Workflow Diagram for DKIST Observing, Calibration and Maintenance Procedure.
- Define set of required operations software tools.
 - Engage Science Working Group
 - Conduct two Operations Sub-working group meetings.
 - Conduct two Data Center Sub-working Group meetings.
 - Produce document describing telescope allocation process and procedures. Discuss with Science Working Group.
- Support Science Working Group with Critical Science Plan development.

E2.1 DKIST Data Center Development

Data Center Milestones

- Recruit key personnel
- Complete Data Center Project Execution and Management Plans
 - Management Review
- Complete Data Center High-Level Requirements and Traceability
 - Requirements review
- Complete Data Center Design Requirements and Traceability
 - Successfully Complete Data Center Conceptual Design Review
 - Successfully Complete Data Center Preliminary Design Review

E2.2 DKIST Instrument and Operations Tools development

- **2nd Generation Instruments.** Start development of prioritized list of 2nd generation instrumentation with Science Working Group and broader community.
- **Operations Tools Development.** This effort is managed by the Data Center Program Manager and will provide management and interface tools for successfully soliciting, reviewing, and executing proposed operational scientific programs.
 - Recruit key personnel
 - Complete Operational Tools High-Level Requirements and Traceability.
 - Conduct requirements review.
 - Complete Operational Tools Design Requirements and Traceability.
 - Conduct Design Review.
 - Develop specification for sky brightness monitor and seeing monitor (required for daily planning of DKIST observations and data quality assessment).
 - Conduct Requirements review.

Adaptive Optics

- Explore design to implement recently demonstrated Limb-AO capability into DKIST AO system during early operations (requested by SWG).
 - Conduct Conceptual Design study.
- DKIST Multi-Conjugate AO.
 - Develop MCAO simulator.
 - Conduct MCAO observations at BBSO and GREGOR.
 - Pursue partnership with Kiepenheur Institute and New Jersey Institute of Technology for joint funding and development of DKIST MCAO.
 - Begin DKIST MCAO design study.

E3. Diffraction-Limited Spectro-Polarimeter On-Line Data Reduction

- Maintain instrument and keep available as user instrument.
- Keep instrument available to perform telescope matrix measurements on Port 2.

E4. NISP/SOLIS

- Install vector spectromagnetograph (VSM) 8542 modulator.
- Replace VSM fans.
- Inspect and determine course of action for VSM camer.
- Implement VSM Guider Dec correction loop.
- Install and implement full-disk patrol (FDP) visible tunable filter (VTF).
- Develop FDP flat-field algorithm
- Replace integrated sunlight spectrometer (ISS) camera.
- Install additional shielding to reduce amount of scattered light in ISS spectrograph.
- Finish removal of VxWorks from SOLIS.
- Select final SOLIS site.
- Plan SOLIS relocation.
- Start SOLIS Relocation.
- If needed, redesign and construct new SOLIS mount.

E5. NISP/GONG

- Install data acquisition system (DAS) at all sites.
- Install entrance window at all sites.

- Perform preventive maintenance visits at all sites.
- Finish planning of Data Center transition to Boulder.
- Begin Data Center transition.

E6. Virtual Solar Observatory (VSO)

- Complete reporting system.
- Start spatial search implementation.

E7. NSO Array Camera (NAC)

- Sky brightness measurements 3500-4670 nm at Kitt Peak.
- Ca I and Mg I spectropolarimetric measurements near 3600 nm.

E8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- · Maintain instrument and keep available as user instrument
- Keep instrument available to perform telescope matrix measurements over broad range of wavelengths.
- Upgrade instrument software to run under broader range of conditions.
- Maintain user friendly data reduction/calibration software; provide software support to users.

E9. Facility IR Spectropolarimeter (FIRS)

- Maintain instrument and keep available as user instrument.
- Finish upgrade of A/D boards for increased frame rate.
- Maintain user-friendly data reduction/calibration software, provide user support.

E10. Dunn Solar Telescope Control and Critical Hardware (Systems Upgrade)

- Perform necessary maintenance to keep telescope available for the solar community.
- Continue efforts to proactively upgrade telescope and other critical hardware systems to the extent possible given financial and personnel constraints.

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

- Work with Queen's University, Belfast to maintain as user instrument.
- Work towards integration into DST data storage for better transfer of data.

• Work with Queen's University to provide software support to users.

E12. Interferometric Bidimensional Spectrometer (IBIS) Camera Upgrade

- Maintain instrument and keep available as user instrument.
- Maintain user friendly data reduction/calibration software; provide software support to users.

E13. Service-Mode Operations at the Dunn Solar Telescope

- Evaluate previous Service Mode cycles.
- Maintain and provide access to data obtained in three previous Service Mode cycles.
- Plan future Service Mode cycles as needed.
- Collect information to set up new specifications and fine-tune already existing spectifications for DKIST operations planning.

E14. Establish NSO Headquarters

- Start the new Cooperative Agreement in January 2015.
- Finalize remodeling design and start renovations in Januayr 2015 of the SPSC building third floor.
- Inaugurate the third floor by March 27, 2015.
- Continue updating the Transition Plan, including posting the Staffing Plan by the end of calendar year 2014.
- Relocate additional NSO staff from Tucson and Sac Peak to Boulder beginning in summer 2015.

APPENDIX F: STATUS OF FY 2014 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2014 Program Plan. (FY 2014 milestones appear in italics below.)

F1. Daniel K. Inouye Solar Telescope (DKIST)

- Utility Building Beneficial Occupancy Date
 - Completed (16 Dec 2013).
- Lower Enclosure Ready for Enclosure Installation
 - Incomplete. Shifted in schedule to FY15 (15 Dec 2014); there were a range of issues that led to this delay (anomalous weather, delayed structure element erections (head ring alignment problems, etc). This is a critical path item and as a result, the construction project is currently showing a 19 August 2019 end date (from the 1 July 2019 baseline).
- S&O Building Steel Erection Starts
 - Incomplete. Although elements of the S&O building structure are underway, e.g., the platform lift steel columns), the S&O building foundations (non-telescope) are not completed until 01 October 2014. At that point, the steel erection for the offices and labs will commence.
- DKIST Telescope Pier complete
 - Completed (28 Feb 2014).
- TMA Factory Acceptance Testing; ship to Hawai'i
 - Incomplete. The TMA Factory Acceptance Testing was broken into two components: 1) coudé rotator 2) mount. The coudé rotator successfully passed acceptance (23 May 2014; provisional in several areas as the error budgets are compared against the combined coudé and mount performance measures); shipment is underway (Sep 2014) to Hawai'i. The mount is scheduled for factory acceptance testing is scheduled to conclude in Mar 2015; we note that there were delays in the initial assembly which caused delays, however this has no impact on the critical path as it has substantial float.
- Enclosure Factory Acceptance Testing; ship to Hawai'i
 - Completed (30 Mar 2014; factory assembly testing). The disassembly is also complete and the majority of items have been shipped to Hawai'i (all items will be shipped by 17 Oct 2014).
- M1 Final Blank Acceptance; begin polishing
 - Completed (30 Jan 2014; M1 Final Blank Acceptance). The M1 Final Blank began polishing 22 Sep 2014 (following successful coarse-fine grinding from Jul-Sep 2014).
- M10 DMS Factory Acceptance Testing complete
 - Incomplete. The fabrication review was successful but identified several items that require resolution before the FAT can be completed. This has slipped into the first quarter of FY15.

- First engineering relocation to Hawai'i
 - Complete. The enclosure lead engineer (Marshall) relocated to Maui. The feedback received has led to improvements in the construction project relocation document.
- VBI Red Fabrication Complete
 - Complete (30 May 2014).
- Engineering/Facility Camera Procurement and Testing
 - Complete (28 Feb 2014).
- Mini-DHS procurement and delivery to Instrument Development Teams
 - Incomplete. The Mini-DHS has been deployed to the VBI but has been pending the need from Instrument Teams as they complete their CDR.
- System Reviews
 - High-Level Software Systems FDR.
 - Incomplete. The requirement documents have been through several rounds of flowdown and interpretation review with the science team. In addition, evolution of the operations model has allowed an increased clarity in the interfaces to the Operations Tools. The HLS FDR will be held in the 2nd quarter of 2015.
 - Cryo-NIRSP CDR
 - Complete (08 Feb 2014); we note that the CDR meeting was completed by that date, however the residual action items took several weeks after that to conclude.
 - DL-NIRSP CDR
 - Incomplete. The date for the CDR has pushed to November 2014.
 - VTF PDR
 - Incomplete. The date for the PDR has shifted to FY2015; we note a design workshop is taking place in October 2014.
 - PA&C FDR
 - Incomplete. Both PA&C and WFC endured staffing transitions over the course of the year which set them back on their review schedules. PA&C is currently scheduled for early 2015 review, pending finalization of its requirement documents.
 - WFC FDR
 - Incomplete. Both PA&C and WFC endured staffing transitions over the course of the year which set them back on their review schedules. WFC is currently scheduled to complete its internal review in November 2014 with an external review shortly thereafter.

F2. Solar Adaptive Optics

- Develop Solar Limb AO system that can lock on prominence structure. Graduate Student Thesis Project.
 - The development of the Solar Limb AO system has been successfully concluded. The Graduate student defended his thesis in June 2014 and has officially graduated from NMSU. He has submitted a thesis publication to Solar Physics.

- Install optical test bench at Sac Peak optics lab. System tests.
 - Completed.
- Perform on-sky tests with Limb-AO at DST.
 - Completed.
- Conclude integration and testing of MCAO at GREGOR and BBSO.
 - System integration of MCAO has been completed at both BBSO and GREGOR. Several MCAO test campaigns have been conducted with NSO personnel performing a leading role at the GREGOR and BBSO/NST.

F3. Diffraction-Limited Spectro-Polarimeter On-Line Data Reduction

- Current demand for this instrument is low because of its location on a separate optical port, preventing it to be combined with other instruments, and duplication of its capabilities in space (Hinode). Efforts to provide a software reduction package to potential users have very low priority, but reduction help is available on demand.
 - Efforts to provide a software reduction package to potential users have very low priority, but reduction help is available on demand.
- Maintain instrument and make available as user instrument on demand.
 - The instrument is available on demand and is used for telescope polarization calibration measurements

F4. NISP/SOLIS

- Complete assembly and install visible, tunable filter for FDP.
 - Assembly completed. Installation scheduled for October 2014.
- Develop technique for flat fielding FDP data.
 - Work on flatfielding with new tunable filter was re-started shortly after SOLIS relocation to Tucson.
- Complete full implementation of VSM guider.
 - Implementation in RA done, area scan guiding enabled.
- Continue to provide VSM, ISS and FDP data online to the solar community and make comparisons with data products from other instruments. Complete transition to VFISV inversion for VSM 6302 vector data.
 - Done and ongoing.
- Support joint observing programs such as the IRIS mission, sounding rocket launches, and queue observing mode at the DST.
 - Done and ongoing.
- Investigate usability of chromospheric synoptic maps as a source field for coronal field/interplanetary field extrapolation and solar wind studies.

- Funding for this work was requested via proposal to NASA.
- Complete cross-calibration of ISS and Sac Peak K-monitor data, successfully merge ISS and K-line monitor, and implement ISS K-line data as the prime source to continue NSO historic K-line dataset.
 - Done and ongoing (additional calibration may be required after relocation of SOLIS is completed).
- Develop new data products for all three SOLIS instruments. Incorporate active-region fields from vector observations to traditional (line-of-sight) synoptic maps.
 - Partially completed. Additional funding to support the last item was requested via proposal to NASA.
- Develop and install new VSM 8542 modulator to obtain chromospheric vector magnetic field observations.
 - Ongoing. All components are in-house and undergoing alignment testing. Installation is scheduled for FY15.
- Install new optical components in VSM calibration assembly to enable full polarimetric calibration in the chromospheric lines.
 - Prefilter deliveries are due in October 2014, and installation is scheduled for FY15.
- Develop cost estimates and plan for future relocation of SOLIS instrumentation.
 - Underway for final relocation. Instrumentation has been moved from Kitt Peak to Tucson and is undergoing testing of new infrastructure.
- Develop plan for transition of NISP staff and resources into restructured NSO organization, i.e. pooled data center and engineering groups.
 - Underway. Recent reduction in staffing has accelerated top-level organizational changes.

F5. NISP/GONG

- Install new data acquisition systems at remote network sites.
 - Scheduled for FY15.
- Assemble and test spare boards (motor amplifier, command, resolver, signal conditioner and tachometer compensation) to expand long-term maintenance inventory.
 - Completed, with on-going modification of boards when they are returned for repair.
- Operate the Learmonth site with expanded network bandwidth to accommodate near-real-time data transfer.
 - Completed.
- *Replace existing turret entrance windows with units having superior coating properties.*
 - Ongoing. All windows are in-house. Two sites (Mauna Loa and Big Bear) have already had their windows replaced.

- Develop full automation of GONG network P-angle registration software (COPIPE), to include improved drift scan processing and quality assurance monitoring.
 - Approximately 80% completed.
- Improve near-real-time full disk calibrations to approach quality requirements for global and local helioseismology products.
 - Underway.
- Add quality control parameters, daily and synoptic flow maps to Ring pipeline code.
 - Maps are now on the Web.
- Add error estimations to level-3 synoptic products (both GONG and SOLIS).
 - Completed for SOLIS.
- Investigate the usability of GONG white light data for determination of classic proxies such as sunspot number and sunspot area.
 - Preliminary tests were performed by applying STARA algorithm to GONG WL images. The algorithm was shown to be successful in identifying sunspots, but it requires additional modifications.

F6. Virtual Solar Observatory

- Add 6-12 new data providers and data sets.
 - Ongoing.
- Develop spatial search capability.
 - On hold for now.
- Develop comprehensive reporting across all data providers.
 - Approximately 80% completed.

F7. NSO Array Camera (NAC)

- Sunspot and quiet Sun spectro-polarimetric observations at 4132 nm in preparation for BBSO/Cyra and DKIST.
 - Observations of sunspots were made at 4135 nm and the results are being prepared for publication. The data show that simple LS coupling does not describe the observed Zeeman splitting of several Fe I and Si I lines in this spectral region, and that there are several molecular lines with effectively negative Lande g-factors. The polarimetric spectra are the first of their kind; the signal to noise levels are currently not good enough to allow quiet Sun observations.
- Spectropolarimetric observations of 1565nm in sunspots.
 - The NAC took several intensity scans of sunspots, but no polarimetric data at 1565 nm were taken during these runs.

F8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

- Maintain instrument and keep available as user instrument.
 - Instrument is working and available
- *Replace failed computer hardware.*
 - Replacement has been made
- Keep instrument available to perform telescope polarization matrix measurements.
 - Telescope calibration was performed in Oct 2014
- *Make instrument available in multi-instrument configuration.*
 - It has been verified that the modulation mechanism can be placed further down stream in the light path, so that combination with other instruments is possible
- *Provide software for data reduction by user.*
 - Software is being made available to all users via the NSO/DST Web site

F9. Facility IR Spectropolarimeter (FIRS)

- Maintain instrument and keep available as user instrument.
 - Instrument is ready and available
- Upgrade AD framegrabber boards for higher throughput. These framegrabber boards should provide for higher frame rates and more flexibility on how the infrared camera can be used.
 - New frame grabber boards have been purchased and have been tested in the instrument. Manufacturer needed to modify firmware and boards were sent back. New attempt will be scheduled for Dec 2015
- *Provide software for data reduction by user.*
 - A software reduction/calibration package has been created and is being made available to allurers via the NSO/DST Web site.

F10. Dunn Solar Telescope Control and Critical Hardware (Systems Upgrade)

- Continue efforts to proactively upgrade telescope and other critical hardware systems to the extent possible given financial and personnel constraints.
 - Several upgrades and repairs have been made. Among them:
 - ° Replacement of guider electronics.
 - $_{\odot}~$ Ordering a spare 400 Hz power supply for powering various telescope servos.
 - $_{\circ}$ $\,$ Replacement of the main UPS batteries and condenser caps.
 - Image server computer replacement.

F11. Rapid Oscillations in the Solar Atmosphere (ROSA) Imaging System

- *Maintain instrument and keep available as user instrument.*
 - Instrument is available and works well.
- Work on streamlining data collection to DST SAN, or other storage media.
 - In cooperation with Queen's University, Belfast, the internal disks of ROSA have been upgraded.

F12. Interferometric Bidimensional Spectrometer (IBIS) Camera Upgrade

- Maintain instrument and keep available as user instrument.
 - Instrument is in working order and available
- *Provide software for data reduction by user.*
 - A data reduction/calibration pacage has been created and is made available to all users via the NSO/DST Web site

F13. Service Mode Operations at the Dunn Solar Telescope

- Evaluate cycle 1 & 2 service-mode campaigns.
 - An extensive report has been written on the first two cycles.
- Conduct at least one, perhaps two, further experiments in 2014.
 - A new experiment has been scheduled for Oct 2014.
- Use gathered information to set up new specifications and fine-tune already existing specifications for DKIST operations planning.
 - Many things, including TAC procedures and proposal handling, have already flowed down into DKIST operations planning.

F14. Establish NSO Headquarters

- Finalize the third floor of the Space Sciences building at the CU east campus. Negotiate the Lease for the HQ in Boulder with CU.
 - Lease with CU completed. Remodeling of the 3rd floor due to start by January 1st.
- Initiate plans for fast-track design and renovation of the third floor space with the goal of completing renovations by March 2015.
 - Ongoing. Plan is to have the 3rd floor available by March 27th, 2015.
- Establish a complete relocation plan of NSO to the new Boulder/Maui sites and make it available to the staff via the Observatory's intranet.
 - First draft of the Transition Plan finished. Staffing plan will be available by the end of calendar year 2014.

APPENDIX G: NSO FY 2015 STAFFING SUMMARY

	Director's Office		NSO/Sunspot		NSO/Tucson	DKIST*				NISP*		TOTAL
	Tucson	Boulder	Sunspot	Boulder		Tucson	Sunspot	Maui	Boulder	Tucson	Boulder	
Scientists	0.50	1.00	3.00	1.00	1.50		1.00		6.00	6.50		20.50
Engineering/Science Support Staff	-	1.00	7.49			20.00		7.00	13.00	7.00	2.00	57.49
Administrative Staff	1.00	2.00	4.20			3.00	1.80	2.00		3.00		17.00
Technical Staff	-				1.00			11.00		5.75		17.75
Maintenance & Service Staff	-		6.86									6.86
												0.00
Total Base Program	1.50	4.00	21.55	1.00	2.50	23.00	2.80	20.00	19.00	22.25	2.00	119.60
AF Supported Science Staff	-		1.00			-				-		1.00
AF Supported Technical Staff	-		1.00			-				-		1.00
Other NSF Projects (AO, FTS/CHEM)	-					-				-		0.00
Graduate Students	-					-				-		0.00
NASA Supported Science Staff	-					-				4.00		4.00
NASA Support Engineering Staff	-		-			-						
NASA Supported Technical Staff	-		-			-				-		
Emeritus Science Staff	-		1.00		2.00	-				-		3.00
Visiting Scientists	-		-			-				-		
Total Other Support	0.00		3.00		2.00	0.00				4.00		9.00
Total Working at NSO	1.50		24.55		4.50	23.00				26.25		128.60

(In Full-Time Equivalents)

*Includes open positions currently being advertised

APPENDIX H: SCIENTIFIC STAFF RESEARCH AND SERVICE

(*Grant-supported staff)

Christian Beck, Assistant Scientist

Areas of Interest

Post-focus instrumentation; data reduction pipelines; high-resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere; development of inversion tools for spectroscopy of chromospheric spectral lines.

Recent Research Results

Dr. Beck extended the inversion code for solar Ca II spectra to cover spectral lines in the near-IR. The code was applied to data obtained at the DST with two different instruments (two publications in *ApJ*) and to full-disk spectra derived with SOLIS (<u>http://www.nso.edu/press/SolarAtmo3D</u>). Three additional publications on fine-structure of sunspots resulted from collaborations with European colleagues. Another publication on the long-term variation of sunspot field strength is in preparation; it uses an extended archive of sunspot observations from different telescopes, including data taken during the DST service-mode runs.

Future Research Plans

New data in mainly chromospheric spectral lines were obtained in a few observation campaigns in 2014. For the analysis of these new data, the available analysis code will be upgraded to use non-local thermodynamic equilibrium (R. Rezaei, KIS, Freiburg, Germany). A similar technique will be developed for the Balmer line of H α for which no suitable analysis technique currently exists. Application of the inversion code to SOLIS full-disk spectra for flare predictions will be investigated. Collaboration with colleagues at the California State University, Northridge will be expanded on both data analysis techniques (with D. Prasad Choudhary) and instrumental developments (with D. Ren).

<u>Service</u>

Beck is a member of the Sac Peak telescope allocation committee and has participated in the planning and implementation of the service-mode experiment at the DST that was executed for the third time in October 2014. Beck also performed several additional observation campaigns at the DST for external investigators. His commitment to the DKIST project has increased during this past year and is expected to continue to increase during the next few years. Beck reviewed several publications for *Astronomy & Astrophysics* and *The Astrophysical Journal* and was referee for a grant proposal outside of the US.

Luca Bertello, Associate Scientist

<u>Areas of Interest</u>

Solar variability and heliospheric physics; with particular interest in investigating the physical processes leading to the different aspects of solar variability and in the calibration of observed solar magnetic field data to enhance the database that supports the analysis of conditions in the Sun's corona and heliosphere. Analysis of Sun-as-a star measurements and their relevance for the domain of stellar physics.

Recent Research Results and Plans for Future Research

Over the course of this year, Bertello has been involved in several projects related to the improvement of the diagnostic value of SOLIS data products. Most of these improvements already have been implemented into the data pipeline, while others are scheduled to go into production later in 2015. One of the major tasks has been the reprocessing of 6302L observations going back to April 2006. This task was necessary to produce a consistent and uniform database and is near completion. In a recent paper published in Solar Physics, Bertello and collaborators at NSO have described a technique to compute spatial variance maps of the solar surface magnetic flux density. These maps can be used to estimate the uncertainty in the results of coronal models. Bertello and colleagues have tested this approach by computing a potential-field-source-surface model of the coronal field for a Monte Carlo simulation of Carrington synoptic magnetic flux maps generated from the variance map. They show that these uncertainties affect both the locations of the sourcesurface neutral lines and the distributions of coronal holes in the models. Furthermore, in collaboration with Dr. Peter Mcniece (NASA/GSFC) Bertello's team included the contribution of uncertainties in the Carrington synoptic magnetic maps in modeling the evolution of the solar wind parameters at Earth computed from the ENLIL/WSA model. The results indicate that some of the discrepancies between observed and computed parameters can be explained in terms of these uncertainties. At the recent Cool Stars 18 meeting in Flagstaff, Bertello presented a study showing the correlation between variations in the line depth and width of solar photospheric spectral lines as measured by the SOLIS/ISS instrument and the total net magnetic flux during the raising phase of solar cycle 24. This investigation may have important implications for the study of the magnetism and dynamo processes in other stars.

Future Research Plans

The main focus of L. Bertello's future research is on improving the quality of current SOLIS longitudinal and vector magnetic field observations, and to enhance the capabilities of the SOLIS ISS instrument.

<u>Service</u>

As a data scientist for SOLIS, Bertello's major responsibility is to provide the solar and heliophysics community with high-quality and reliable data. During 2014, Bertello has been a reviewer of publications for *Solar Physics* and other journals. As a former lecturer in physics, Bertello still maintains a strong connection with former UCLA students by helping their post-college career with letters of recommendation.

*Olga Burtseva, Assistant Scientist

Areas of Interest

Flares; magnetic field; local helioseismology; solar activity.

Recent Research Results

Dr. Burtseva (in collaboration with G. Petrie, A. Pevtsov and non-NSO researchers) continues to study the evolution of magnetic field in flaring active regions. In order to relate abrupt changes of the LOS magnetic field observed during strong flares to the coronal restructuring, and investigate the origin of magnetic field changes during flares, the spatial and temporal connection between magnetic field changes during X-class flares, observed by GONG and HMI, and the location of Hard X-Ray (HXR) emission observed by RHESSI has been investigated.

The field changes and HXR emission were found to be spatio-temporally related but not co-spatial nor simultaneous. Some of the field changes propagate with speed close to that of the HXR footpoint at a later phase of the flare, often after the HXR signal reaches its maximum, when the footpoint starts moving away from the polarity inversion line, i.e., the field changes follow the same trajectory as the HXR footpoint, but at an earlier time. It was also shown that in the strongest X-class flares, amplitudes of the field changes peak a few minutes earlier than the peak of the HXR signal. These results suggest that the major coronal magnetic field changes occur before most of the particle acceleration and HXR emission. These results were presented on the AAS 224th meeting in Boston and a paper has been submitted to the *Astrophysical Journal*.

Future Research Plans

O. Burtseva plans to continue working on the evolution of magnetic field associated with solar flares observed by GONG, HMI and SOLIS. She will resume her analysis of flux cancellation events during major flares using HMI vector magnetic field data. She will also work on cylindrical symmetry modeling of sunspots, to see how well the model works by comparing photospheric and chromospheric LOS magnetic field with vector field.

Serena Criscuoli, Assistant Scientist

<u>Areas of Interest</u>

High-spatial resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere; post-focus instrumentation; radiative transfer; numerical simulations; solar irradiance variations.

<u>Recent Research Results</u>

Dr. Criscuoli recently worked on several topics in the framework of the 'Areas of Interests' mentioned above. She analyzed 3-dimensional magneto hydrodynamic simulations of the solar photosphere to investigate the following subjects: the effects of spatial resolution in retrieving properties of small-size magnetic elements from observations; the different physical properties of active and quiet regions, and the implications for solar irradiance studies; the interpretation of irradiance measurements in the visible spectral range; the observational signature of local dynamo; the effects of local dynamo on the determination of solar chemical abundances. She continued her study on the fractal and multifractal properties of active regions as precursors of solar flares. She also investigated: the properties of a delta-spot through the analysis of high spatial resolution data acquired at the Swedish Solar Telescope; the long-term variations of properties of quiet Sun through the analysis of SOLIS data; the accuracy of HMI measurements through the analysis of simulations and HMI data. Results of her investigations are summarized in six papers published in *Astronomy & Astrophysics, The Astrophysical Journal* and *Solar Physics,* and have been presented at conferences as oral and poster contributions.

Future Research Plans

S. Criscuoli plans to continue her research on the observational signature of local dynamo, the observational properties of small-size magnetic elements and the improvement of solar photosphere models employed for solar irradiance reconstructions.

<u>Service</u>

S. Criscuoli mentored an REU student during summer 2014. She is a member of the Sac Peak telescope allocation committee and has contributed to the planning and execution of the third cycle of service-mode observations at the DST. She is responsible for user support, as well as improve-

ment, of the IBIS data calibration software. She is a scientific consultant for the DKIST and is responsible for developing one of the DKIST critical science cases. In 2014 she was a referee for scientific journals.

David F. Elmore, Instrument Scientist

Areas of Interest

Development of ground-based spectrograph and filter-based polarimeters, including both current instruments at NSO and new instruments for the Daniel K. Inouye Solar Telescope. Collaboration with NSO staff and visiting scientists to explore new spectropolar-imetric capabilities—spectral regions, processing techniques, and measurement calibration.

Future Research Plans

Elmore will continue working with prospective instrument developers to define and develop instrumentation for the DKIST. He will apply his thorough understanding of telescope calibration at the Dunn Solar Telescope toward development of the telescope calibration plan for the DKIST. He also plans to utilize existing instruments at NSO, such as SPINOR, ProMag, and IBIS, to advance spectro-polarimetric techniques.

<u>Service</u>

Elmore is Optical Systems Scientist for the DKIST. In that role he works with instrument builders and DKIST team members to define the instruments and their interfaces. As DKIST Optical Systems Scientist, Elmore has created a Polarimetry Working Group that is addressing detailed issues related to the end-to-end polarization calibration of the DKIST and its instruments.

Mark S. Giampapa, Astronomer

Areas of Interest

Solar and stellar magnetic activity; stellar dynamo properties; star-exoplanet interactions.

Recent Research Results

M. Giampapa and Vincenzo Andretta (INAF—Naples) have finalized their measurements of the He I triplet lines at 587.6 nm and 1083.0 nm, respectively, in a sample of G and F dwarf stars with detected coronal X-ray emission. A paper for submission to *The Astrophysical Journal* is planned for FY15. Giampapa also completed an initial analysis of the time series of SOLIS ISS spectra showing that a simple two-component model of the solar photospheric magnetic field showed promise in accounting for bisector and core depth variations in the magnetically sensitive Mn I line at 539.5 nm. In collaboration with Kepler Project Scientist Steve Howell, Giampapa contributed Sun-as-a-star context for a paper on characterization of solar-like exoplanet systems with terrestrial-size planets.

<u>Future Research Plans</u>

Giampapa is collaborating with M. Penn (NSO) in obtaining simultaneous Ca II K and IR spectra of solar plages to measure both photospheric and chromospheric field strengths. The broad objecttive is to develop a more accurate empirical correlation between chromospheric heating and chromospheric field strength will be investigated. In collaboration with NSO colleagues A. Pevtsov and L. Bertello, Giampapa plans to use the SOLIS ISS for long-term studies of the Sun-as-a-star, specifically the variation of line bisector amplitudes and Zeeman broadening effects in photospheric features during the solar cycle. In collaboration with J. Hall (Lowell Observatory), Giampapa is planning programs to investigate the magnetic activity of solar-type stars in the solar-

age and metallicity cluster, M67, which the K2 mission will monitor for 76 days in FY15. Giampapa, along with A. Pevtsov and prospective Co-Is, B. Brown (CU) and K. Strassmeier (MPI-Potsdam), is planning a proposal submission to the newly established Solar-Stellar component of the NASA LWS program.

<u>Service</u>

M. Giampapa is the Deputy Director for the National Solar Observatory but will transition to the NSO Tucson Site Leader at the implementation of the new Cooperative Agreement. As Site Leader, he will continue to carry out supervisory responsibilities for the NSO Tucson/Kitt Peak program. In this role, he has overview responsibilities for the scientific and instrument development activities at the McMath-Pierce jointly with McMP Telescope Scientist Matt Penn. Giampapa is the chair of the NSO Kitt Peak Telescope Allocation Committee (TAC) and program scientist for the McMath-Pierce nighttime program. With Matt Penn, Giampapa is working with a consortium for divestiture of the McMath-Pierce in FY 2017. Giampapa represents the NSO in discussions and negotiations with the NOAO, particularly with respect to mountain support of NSO/Kitt Peak operations. He continues to work in support of the new NSO Diversity Advocate, Dr. John Liebacher. Like other NSO scientific staff members, Giampapa participates in educational outreach activities, including K-12, undergraduate, graduate, and general public educational programs and activities. Giampapa is an adjunct astronomer at the University of Arizona.

Sanjay Gosain, Assistant Scientist

<u>Areas of Interest</u>

Solar flares, erupting filaments and CMEs; helicity properties of solar active regions; solar cycle related magnetic field variations; instrumentation, polarization calibration, modulator development, optical design study.

Recent Research Results

The main areas of S. Gosain's research in 2014 were the study of electric currents in uniformly twisted sunspots and the derivation of force free parameter at different heights, photosphere, chromosphere and corona. It was found that twist in three layers corresponds well and is slightly higher in lower layers. For the chromospheric and coronal layers, the information was derived by linear force free modeling of twisted structures seen in AIA images. A decomposition method was proposed for isolation of electric currents arising due to twist from currents arising due to fine scale spatial variations of vector magnetic field in areas such as penumbral filaments. The results are published in the *Astrophysical Journal*, 793(1):15, 2014.

Further, statistical properties of current helicity density in active regions and their hemispheric pattern were studied in relation to the solar cycle, using vector synoptic maps from the SOLIS VSM. Also, the correspondence study between current helicity at photosphere and kinetic helicity of subsurface plasma flows, inferred from local helioseismology, was carried out. These results are published in *Solar Physics* 289:2399, 2014 and *Solar Physics* 289:475, 2014.

Also, global nonlinear force-free field (NLFFF) extrapolations of coronal field were performed using vector synoptic maps from SOLIS VSM. These are first such global extrapolations from our unique data set. The first results are described in the *Astrophysical Journal*, 772(1):52, 2013; *Astronomy & Astrophysics*, 562:105-113, 2014; and *Solar Physics*, 289(11):4031, 2014.

Future Research Plans

Dr. Gosain plans to continue working on (i) completing the 854.2-nm modulator installation and calibration and observing full Stokes data for solar active regions in this chromospheric line; (ii) the design study of the Solar Physics Research Integrated Network Group (SPRING); and (iii) scientific research using vector magnetic field observations.

<u>Service</u>

During this period, Dr. Gosain was mostly involved in the development of the polarization modulator assembly for the chromospheric 854.2 nm line, in close collaboration with Dr. Jack Harvey (NSO). Ferroelectric liquid crystals (FLC) were procured and tested in the lab for their retardance properties. Their spatial uniformity was examined and orientation of switching axis was verified. Further, their temperature response was also measured. Regarding the efficiency of modulation in the planned 854.2 nm wavelength region, simulations were carried out and optimum angles of the various polarizing optics were determined. Finally, the practical modulation and demodulation matrix of the modulator were determined and found to be in agreement with calculations. Interference filters for the modulator package (narrowband) and for calibration optics (dual passband) were ordered, and installation of the new modulator and filters for calibration assembly are scheduled for the start of the new calendar year. Dr. Gosain was also involved in the design study and preparation of the science requirement document for SPRING (a new network being proposed by the Kiepenheuer Institute (KIS) in Freiburg, Germany).

Brian J. Harker, Assistant Scientist

<u>Areas of Interest</u>

Stokes spectropolarimetry of the photosphere; Stokes inversion techniques; spectropolarimetric data reduction; flare-related changes in active-region vector magnetic fields; parallel processing techniques for data reduction.

Recent Research Results

B. Harker, with NSO colleague Alexei Pevtsov, published a paper in *The Astrophysical Journal (ApJ* 778, 175, 2013) about a flare-related magnetic transient they studied in NOAA AR11429. The paper showed that a transient patch of oppositely-signed flux which emerged during the flare was not an artifact, but in fact represented a real change in the magnetic structure of the atmosphere during the flare. Dr. Harker is currently building a database of more magnetic transient events from the SDO/HMI data catalog.

Dr. Harker worked with Drs. A. Pevtsov and L. Bertello on a comparison of disc-integrated Ca II 8542 observations with the SOLIS/ISS with disc-resolved observations of the same line observed by the SOLIS/VSM. It was determined that an "ISS-like" "observation" could be created from a manual disc-integration of the VSM spectral data, to a point. This opens the door for solar-stellar connection studies; for example, determining what percentage of stellar surface may be covered with plage by examining similarities to the Sun's own integrated spectrum. A paper on this was published in the proceedings of the 18th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, 9-13 June 2014.

Dr. Harker is also working with Dr. J. C. del Toro Iniesta (IAA-CSIC) on a Fourier analysis of Stokes profiles (in wavelength space) to diagnose their inherent information content. Synthetic Stokes profiles are simulated from Dr. Han Uitenbroek's RH code, using MHD simulation domains

from Dr. Mathias Rempel. Synthesizing the Stokes profiles at high spectral sampling (2 milli-Angstroms) allows us to see what effect a change in sampling has on the integrated power spectra, and altering the noise level of the synthetic profiles will help determine the proper spectral sampling for a given spectral line, at which we retain the most spectral information possible. This will be important for future instrument design.

<u>Future Research Plans</u>

Dr. Harker plans to continue his work into the nature of magnetic transients (MT) by building a comprehensive database of HMI-observed MTs and their interpretations. Also, with the approach of the new SOLIS/VSM 8542 vector modulator, Dr. Harker has begun exploring potential pipeline applications for the inversion of 8542v vector data, using the NLTE NICOLE code, as well as a new algorithm recently developed by Dr. Christian Beck.

<u>Service</u>

Dr. Harker participated in the preparation of two grant proposals; the first, which as been funded, was for investigating flare-related changes in active region magnetic fields. The second was for a new NSO Research Experience for Undergraduates (REU) program; the funding results for that proposal are expected in January 2015.

John W. Harvey, Astronomer

<u>Areas of Interest</u>

Solar magnetic and velocity fields; helioseismology; instrumentation.

Recent Research Results

During FY 2014, Dr. Harvey worked on SOLIS and GONG instrument development and maintenance. This work continues to consume nearly all available time so, as has unfortunately been the case for many years, little research was done. A fortunate observation of a large solar flare at the peak of its emission was the focus of most of his research. SOLIS VSM spectra of intensity and circular polarization using the chromospheric 854.2 nm line showed that the total magnetic flux in the flaring area was nearly identical in the photosphere and the chromosphere. However, the flux densities were usually lower in the chromosphere – a consequence of spreading of magnetic field lines with increasing height. This spreading also causes a few small areas with higher flux density in the chromosphere than below. A new method of extracting magnetic information from the polarized flare line profiles was tested and is promising but needs more development. Harvey collaborated on a study led by Gordon Petrie of white light flares observed with GONG and the SORCE satellite total irradiance monitor. He authored two technical notes concerning calibration and image quality of the SOLIS VSM. Studies of simultaneous chromospheric observations with the SOLIS VSM and the IRIS satellite were continued at a low level. In instrumental work, Harvey completed the SOLIS FDP visible tunable filter and located and fixed the major problem with the SOLIS FDP guider that permitted it to start operation. A new modulator for chromospheric vector magnetic field measurements was constructed by Sanjay Gosain and Harvey. Thanks to his Co-I position on a NASA Grand Challenge grant, geometric correction of 30 years of daily magnetograph data was started jointly with Andres Munoz-Jaramillo. This will greatly improve quality to nearly that of contemporary observations and will enable a wide range of improved solar cycle studies.

Future Research Plans

During FY 2015, J. Harvey will install and adjust the SOLIS FDP visible tunable filter (after the FDP is restored to operation following severe water damage), assist with bringing the VSM guider to full operation, install a new modulator for VSM chromospheric vector field measurements, continue to concentrate on improved reduction of SOLIS and GONG data, and continue research previously started. Harvey hopes to be able to concentrate more on research after his October 2014 transition to halftime. He is especially interested in using the archive of old magnetograms to estimate of past meridional flow patterns in the solar photosphere. He is preparing his invited memoirs for the journal *Solar Physics* and two invited keynote talks for international meetings.

<u>Service</u>

J. Harvey has responsible instrumental and scientific roles in the GONG and SOLIS projects. During FY 2014, he served on a Naval Research Laboratory triennial review of their space physics program. He is a co-investigator on the IRIS satellite project and a NASA Grand Challenge program.

Frank Hill, Senior Scientist

Areas of Interest

Helioseismology; asteroseismology; fluid dynamics of the solar convection zone; the solar activity cycle; virtual observatories; solar magnetic fields; space weather.

<u>Recent Research Results</u>

Dr. Hill continues to perform research in helioseismology. Working with R. Howe and others, Hill continues to track the progress of an east-west zonal flow in the solar interior known as the torsional oscillation as it slowly migrates from the solar poles to the equator. Recent data indicate that the poleward flow for Cycle 25 is still very weak, and that a puzzling low-latitude feature may be appearing.

Hill continues to work with R. Komm on north-south asymmetries of the large-scale flows in the Sun. This work shows that the Cycle 24 torsional oscillation poleward flow was first detected in the southern hemisphere, while the equatorward branch first appeared in the north.

Hill has been working with graduate student Teresa Monsue, and Dr. Keivan Stassun (Vanderbilt U.), to apply a new analysis technique of acoustic oscillation power map movies to GONG H α images during flares. This study has revealed a distinctive pattern of acoustic power suppression and recovery during a flare that is related to the height-dependence of the oscillation amplitudes and the visibility of different layers during a flare.

Future Research Plans

Hill will be participating in a NASA Grand Challenge (P. Martens, PI) grant to constrain dynamo models with realistic flows inferred from helioseismology. He will also be working on improvements to the helioseismic far-side maps, with the goal of using them to improve the AFRL ADAPT magnetic field, F10.7 flux, and EUV flux forecasts.

<u>Service</u>

Hill is the NSO Associate Director for the NSO Integrated Synoptic Program (NISP), which combines SOLIS and GONG. He continues to participate in the development of the Virtual Solar Observatory, which was released to the public in December 2004. Hill typically supervises several staff, currently eight scientists, one manager, and one programmer. He acquired funding from the

US Air Force Weather Agency (AFWA) in 2009 to develop and install the H α observing capability in the GONG network. AFWA has subsequently provided operational support for GONG in FY 2011-14. Hill participates in about four proposals a year for outside funding, and was recently was awarded a NASA Infrastructure grant to support NISP operations.

Hill typically reviews ten proposals annually for the NSF and NASA, as well as five papers for *ApJ*, *Solar Physics*, etc. He serves on the scientific organizing committee for international scientific meetings, and is a member of the European HELAS Board. He is currently participating in the development of a new network to obtain multi-wavelength observations for helioseismology, solar magnetometry, and space weather.

*Kiran Jain, Associate Scientist

Areas of Interest

Global and local helioseismology – solar cycle variation; multi-wavelength helioseismology; subsurface dynamics; solar activity – irradiance modeling; Sun-Earth connection.

Recent Research Results

The availability of continuous high-cadence and high-spatial resolution Dopplergrams allows us to study sub-surface dynamics that may be further extended to explore precursors of the solar activity. Since *p*-mode power is absorbed in high magnetic field regions, the helioseismic inferences in these regions are associated with large errors. In order to validate results from helioseismic studies, Dr. Jain and colleagues used Dopplergrams from both space-borne (Helioseismic Magnetic Imager (HMI)) and ground-based (Global Oscillation Network Group (GONG)) observations to infer horizontal flows in photospheric and sub-photospheric layers in and around several active regions. The photospheric flows are calculated using local correlation tracking (LCT) method while ring-diagram analysis technique is used to infer flows in the sub-photospheric regions. A detailed study was carried out between flows in shear layer and photospheric layer in order to understand similarities and discrepancies in these results.

Dr. Jain also applied the technique of ring-diagrams to study the temporal variation of the horizontal velocity in sub-surface layers beneath several active regions during their disk passage in the rising phase of solar cycle 24. The study was focused on large active regions which survived more than one rotation during their lifetimes. Finally, these active regions were grouped by their morphology. This study clearly demonstrates that the characteristics of horizontal flows are dominated by the morphology of active regions.

<u>Future Research Plans</u>

K. Jain will continue to work on multi-spectral data in order to obtain a better picture of the excitation and damping mechanisms of solar oscillations. She will also apply the techniques of helioseismology to probe the characteristics of seismic waves propagating in the layers above the solar surface. The waves, which are evanescent below the acoustic cut-off frequency and trapped in the interior, change their characteristics at high frequencies and propagate through the atmosphere. These high-frequency waves may play an important part in the heating of the chromosphere and higher solar atmosphere. She will investigate the propagation characteristics of these traveling waves that may unveil important clues to the structure of the solar atmosphere: temperature, density, formation height of spectral line, etc.

As active regions are the main drivers of space weather, Jain will study the sub-surface weather in order to explore precursors of the emergence of such regions. She will continue her study of

subsurface properties of these regions and explore the connection between subsurface dynamics and characteristics of the active regions.

Solar cycle related changes in global and local frequencies, and other mode parameters will also be studies and a detailed comparison between cycles 23 and 24 will be made in order to understand the precise relationship between solar oscillations and magnetic activity.

<u>Service</u>

Jain serves as the Program Scientist of the Interior Science Group of the NSO Integrated Synoptic Program (NISP), and is a member of the NSO Scientific Personnel Committee (SPC). She was the leading editor of the proceedings of NSO Workshop #27 entitled "Years of Seismology of the Sun and Stars".

Stephen L. Keil, Astronomer

Areas of Interest

Solar activity and variability; astronomical instrumentation; solar convection and magnetism; coronal waves; educational outreach; Daniel K. Inouye Solar Telescope.

<u>Recent Research Results</u>

S. Keil developed and compared results from several techniques for filling in gaps from missing data. The programs he developed will be useful for completing any synoptic data set with missing values. Applying these techniques to the daily Sac Peak and SOLIS Ca II K-line measurements, he confirmed the detection of solar differential rotation when the Sun is viewed as a star.

Future Research Plans

Keil plans to complete his work on Ca II K-line variability in the Sun when viewed as a star. A manuscript is in preparation. He continues to work on the problem of advanced predictors of solar activity.

<u>Service</u>

Keil represented the NSO at the Solar Eclipse Workshop held at Sacramento Peak and presented a talk on the Daniel K. Inouye Solar Telescope. He staffed the NSO booth at the fall 2014 meeting of the American Geophysical Union, performing outreach to both the geophysics community and to the public. He consulted with the NSO Director on the new NSO Cooperative Agreement and on various aspects of moving NSO Headquarters to Boulder.

*Shukirjon S. Kholikov, Associate Scientist

Areas of Interest

Helioseismology; data analysis techniques; time-distance methods.

Recent Research Results

Shukur Kholikov works primarily on time-distance applications using GONG++ data. He has developed a time-distance pipeline, which provides travel-time maps of daily GONG-network data and produces reconstructed images with specified filters. At present, the pipeline has been tested to produce several types of specific travel time measurements.

The main focus of the pipeline is deep meridional flow measurements. Meridional flow measurements were obtained by using GONG spherical harmonic (SH) time series for 1995-2011 using travel-time differences from velocity images reconstructed from SH coefficients after

applying phase-velocity and low-filters. The obtained depth profile shows a distinct and significant change in the nature of the time differences at the bottom of the convection zone. Travel-time measurements are affected by center-to-limb variations across the solar disk. Corrections of this artifact on meridional flow measurements revealed an evidence of return flow at ~60 Mm depth of the solar interior. Using three years of GONG data, a detailed meridional flow profile of both poleward and equatorward components were obtained. Development of an inversion procedure to extract equatorward components of the deep meridional flow is in progress.

In order to understand the properties of the solar acoustic waves, a comparative analysis between cross-correlation and mutual information measurements were performed. It was shown that using mutual information theory can provide more robust results in some fields of local helioseismology, in particular on lifetime measurements of solar high degree acoustic modes.

<u>Future Research Plans</u>

Dr. Kholikov will continue to improve the time-distance pipeline and provide the scientific community with specific GONG data for local helioseismology analysis. The main focus will be the deep equatorward return flow measurements involving GONG, MDI and HMI data series. He also will be involved on a new time-distance based solar far-side mapping studies.

<u>Service</u>

Dr. Kholikov will monitor the quality of available local helioseismic data products provided by NISP project. He also provides time distance measurements and high degree SH time series of GONG data by request.

*Rudolf W. Komm, Associate Scientist

<u>Areas of Interest</u>

Helioseismology; dynamics of the solar convection zone; solar activity and variability.

<u>Recent Research Results</u>

Dr. Komm continues to perform research in helioseismology. He is deriving solar sub-surface fluid dynamics descriptors from GONG data analyzed with a ring-diagram. Using these descriptors, he was able to derive, for example, the divergence and vorticity of solar sub-surface flows and study their relationship with magnetic activity. Komm is exploring the relationship between the twist of subsurface flows and the flare production of active regions and started producing daily full-disk maps of the normalized helicity parameter in collaboration with A. Reinard (NOAA/SWPC). Komm is searching for a signature of helicity flow from the solar interior to the photosphere, in collaboration with NSO colleagues S. Gosain and A. Pevtsov, and has derived the subsurface helicity of long-lived activity complexes and the hemispheric helicity rule of subsurface flows. Komm is studying the solar-cycle variation of the zonal and the meridional flow in the near-surface layers of the solar convection zone, in collaboration with F. Hill, and R. Howe.

Future Research Plans

Komm will continue to explore the dynamics of near-surface layers and the interaction between magnetic flux and flows derived from ring-diagram data, and will focus on the relationship between subsurface flow characteristics and flare activity in active regions. He will focus on the daily variations of subsurface flows of active regions and search for a signature of helicity flow from the solar interior to the photosphere. He will also continue to explore the long-term variation of subsurface flows.

<u>Service</u>

Komm continues as coordinator of the Local Helioseismolgy Comparison Group (LoHCo). He supervises undergraduate and graduate students who participate in NSO's summer REU and SRA programs.

John W. Leibacher, Astronomer

Areas of Interest

Helioseismology; atmospheric dynamics; asteroseismology.

Recent Research Results

J. Leibacher's recent work has focused on the evolution of solar active regions as seen by GONG and SDO, and the treatment of low-degree spherical harmonic mode frequencies to better probe the deep solar interior. Work on various aspects of a new technique for measuring solar subsurface meridional circulation and its variation with the solar cycle was published. Work on the variation of the helioseismic signal with altitude in the solar atmosphere and the intercomparison of measurements from different instruments and different techniques is waiting on collaborators.

Future Research Plans

Ideas about the observational signature of the convective excitation of p-mode oscillations are being pursued with data from GONG as well as instruments onboard the SOHO spacecraft with collaborators at the Institut d'Astrophysique Spatiale (Orsay, France) and the Observatoire de Paris–Meudon. The application of helioseismic techniques to stellar oscillations and comparison with ground-based Ca K line observations started in collaboration with the CoRoT mission and is being pursued in the framework of the Kepler-K2 mission, and modifications to the SDO/HMI and AIA frequency analysis are being pursued. The search for flare-related changes in the solar interior as manifested in helioseismic "ring-diagrams", and application of gap-filling strategies to helio- and asteroseismic time series continues apace.

<u>Service</u>

Dr. Leibacher provides scientific oversight of the *NSO Newsletter*, as NSO Diversity Advocate and vice-chair of the AURA Workforce Diversity Committee, and organizes the weekly seminar series. Leibacher has been a mentor to several undergraduate (REU) students and two graduate students using GONG data, has been the external examiner on six PhD theses and a member of seven PhD juries recently. He maintains the American Astronomical Society/Solar Physics Division *SolarNews* WWW site. He is a member of the Fachbeirat (scientific advisory committee) of the Max-Planck Society's Institute for Solar System Research (Göttingen), chair of the High Altitude Observatory/National Center for Atmospheric Research External Advisory Committee, advisor to several external projects, member of the Working Group for Ground-based Network in support of *Solar Physics*.

Jose Marino, Assistant Scientist

<u>Areas of Interest</u>

Solar adaptive optics and multi-conjugate adaptive optics; high-resolution solar observations; atmospheric tomography; point spread function estimation; solar adaptive optics modeling.

Recent Research Results

J. Marino presented the results from a feasibility study of a novel layer oriented wavefront sensor approach with applications to solar multi-conjugate adaptive optics (MCAO). The proposed new sensing approach attempts to simplify high altitude wavefront sensing by providing a direct measurement of the wavefront phase originating from a high layer in the atmosphere. Marino also presented current results obtained from the project, currently under way, to build a new solar adaptive optics simulation package. The goals of the new simulation package are to provide a flexible simulation package capable of fast and accurate simulations of solar adaptive optics and MCAO systems.

Future Research Plans

Dr. Marino will continue the development of the new solar adaptive optics and MCAO simulation package. This package will be used to study the performance of new generation solar adaptive optics systems for large aperture telescopes, such as the DKIST. Marino is currently involved in a project to build a solar MCAO system at the Big Bear Solar Observatory. He will continue to work in the off-limb adaptive optics system that was developed by G. Taylor as part of his PhD thesis project.

<u>Service</u>

During 2014, Dr. Marino reviewed two scientific papers submitted to *Solar Physics* and *Chinese Optics Letters*. He is also involved in a graduate student project undertaken by CU physics graduate student Courtney Peck. The project is supervised by Friedrich Wöger and Mark Rast.

Valentín Martínez Pillet, NSO Director

<u>Areas of Interest</u>

Solar activity; Sun-heliosphere connectivity; magnetic field measurements; spectroscopy; polarimetry; astronomical instrumentation with an emphasis on the Daniel K. Inouye Solar Telescope.

Recent Research Results

Before joining NSO as Director, Dr. Martínez Pillet was leading the Imaging Magnetograph eXperiment (IMaX) for the balloon borne SUNRISE solar telescope (a Germany, Spain and USA collaboration). IMaX/SUNRISE has flown twice from the Artic circle within the Long-Duration Balloon program of NASA (June 2009 and June 2013). The data obtained during the first flight has produced the most accurate description of the quiet Sun magnetic fields, reaching unprecedented resolutions of 100 km at the solar surface and a sensitivity of a few Gauss. These data have produced well over 40 papers in the last few years, describing a large variety of processes including the discovery of small-scale supersonic magnetized flows. These jets have been recently identified in the *Hinode* satellite data that provide full Stokes spectral profiles and allow for a detailed study of the atmospheric context in which they are generated. Using inversion techniques, such a study is being performed in the context of the PhD of C. Quintero (IAC). It is expected that the data from the second flight will produce results of a similar impact.

Dr. Pillet was also leading (as co-Principal Investigator) the design and construction of the Polarimetric and Helioseismic Imager for the Solar Orbiter mission (a Germany, Spain and France collaboration).

<u>Future Research Plans</u>

As Director, Dr. Pillet has overall responsibility for the operation of NSO and the effort to develop the Daniel K Inouye Solar Telescope, to maintain and rejuvinate the NSO synoptic program, and prepare for observatory operations at the new NSO directorate site in Boulder, Colorado. Dr. Pillet plans to maintain an active role in the analysis of the data from the second IMaX/SUNRISE flight. This flight received ground support from several of the NSO facilities including the SOLIS VSM instrument. The full-disk, vector magnetic capabilities of SOLIS nicely complement the highresolution data from IMaX/SUNRISE during this second flight.

Dr. Pillet plans to establish collaborations with the NISP scientists on quantifying the flux history of active regions with an emphasis on their decay phase.

<u>Service</u>

Dr. Pillet is Director of the National Solar Observatory. In the past, he has provided services for a variety of international institutions, including: member of the High Altitude Observatory Science Advisory Board; member of the DKIST Science Working Group; member of the European Space Agency Solar System Working Group; former President of the International Astronomical Union Commission 12 on Solar Radiation and Structure; former President of the International Astronomical Union Division II The Sun and the Heliosphere; and member of the Editorial Board of the journal *Solar Physics*. In 2014, Dr. Pillet became a member of the Kiepenheuer Institut für Sonnenphysik (Freiburg, Germany) scientific advisory committee. KIS is a partner on DKIST contributing with a first-light instrument.

Dr. Pillet has been the PhD advisor of three students at the IAC (Tenerife) and supervisor of three postdoctoral scientists from various international institutions.

Matthew J. Penn, Associate Astronomer

<u>Areas of Interest</u>

Spectropolarimetry; near-IR instrumentation; solar atmosphere; oscillations and magnetic fields.

Recent Research Results

M. Penn reviewed the current state of solar physics research in the infrared spectrum in an invited review paper for the on-line journal *Living Reviews in Solar Physics* (2014, v11 no2). Working with NSO colleagues F. Watson and W. Livingston, sunspot magnetic field and brightness data from infrared measurements at the McMath-Pierce (McMP) were combined with observations from MDI to show that both instruments reveal a change in sunspot magnetic fields, but little change in sunspot brightnesses (*ApJ* 787, 2014). With Watson and a team from Sac Peak, Penn is involved in a detailed comparison of infrared intensity measurements of sunspot magnetic fields from the McMath-Pierce with full-Stokes polarimetry of the same sunspots taken from Sac Peak. Penn has analyzed the Stokes spectra of several Fe I and Si I lines near 4135 nm and has found that these measurements will constrain the configuration interaction and intermediate coupling models describing the formation of these lines. Working with a team from NASA/GSFC, Penn has captured observations of An I 1523 nm, which shows hyperfine splitting from magnetic fields.

<u>Future Research Plans</u>

With NASA/GSFC, Dr. Penn is developing a 5/10/14 micron infrared imaging system, will continue with spectropolarimetry at 4 microns, and is developing eclipse experiments for 2017.

<u>Service</u>

Dr. Penn is establishing partners for the McMP Operations Consortium, which will take over operations of the facility in 2018. Penn is involved with the DKIST development, particularly the IR and coronal instrumentation for the DKIST (Cryo-NIRSP and DL-NIRSP) and with the DKIST Science Working Group to produce the DKIST Critical Science Plan. With the BBSO/NST/Cyra cooled spectrograph instrument, Penn has done four engineering runs at BBSO. "First-light" science data is expected in early 2015. Penn is a research advisor for NJIT graduate student Xu Yang. Yang's thesis project will use 4135 nm spectropolarimetry with Cyra to measure quiet-Sun magnetism with high precision. Penn is advising postdoctoral research associate Fraser Watson, a graduate from the University of Glasgow, with additional studies of the long-term sunspot magnetic field evolution. Penn is in charge of the NSO summer Research Experiences for Undergraduates (REU) program and has applied for more funding from the NSF to continue the program. He is planning to hire undergraduates from the University of Arizona to work on an eclipse experiment. Penn has mentored Tucson high school student Nick Irvin for his senior exit project. The project involved making remote observations at the McMath/Pierce from Cienega High School. Penn will continue the project with Joseph Putko from Dublin School in New Hampshire. Penn continues his work with the NASA/SHMOWG, and has joined the AAS 2017 Eclipse task force. As part of the task force, Penn is developing citizen science projects for the eclipse.

Gordon J. D. Petrie, Associate Scientist

<u>Areas of Interest</u> Solar Magnetic Fields

Recent Research Results

G. Petrie wrote two review articles related to the solar polar fields. The first, for *Space Science Reviews*, discussed the extended solar cycle observed at high latitudes. This focused on the highlatitude corridor between the active regions and polar fields, across which extended cycle phenomena (ephemeral bipoles, coronal EUV emission, torsional oscillations) travel equatorward while decayed active region flux and filaments travel poleward. Both the equatorward and poleward transport appears to be due to the meridional flow, consistent with the well-known Babcock-Leighton phenomenological model. The second paper, for *Living Reviews in Solar Physics*, discuss the polar field observations, photospheric flux transport, and the coronal and heliospheric consequences of the polar fields in more depth. Refereeing and publication of the second paper have been delayed by management difficulties at *Living Reviews*.

Petrie showed that a calculation invented by G. Fisher (UC Berkeley) for estimating total photospheric Lorentz force changes associated with flares can reliably produce local estimates in large structures within regions composed of strong magnetic field, such as sunspots and strong neutral lines. This had often been assumed to be true in practice without being demonstrated in theory. A paper appeared in *Solar Physics*.

With 2013 REU student Darryl Seligman (U. Pennsylvania) and NSO's Rudi Komm, Petrie compared the magnetic and current helicities of a large sample of active regions to the kinetic helicity of the interior flows beneath. They found correlations between the surface and subsurface helicities on long (years) and short (days) timescales, providing evidence of a causal link between

interior helical flows and the twisted coronal fields that produce flares and CMEs. A paper appeared in *The Astrophysical Journal*.

With 2014 SRA student Sophie Ettinger (U. Chicago), Petrie is studying in detail the relationship between polar field reversals and active region decay using a long (1974-present) series of NSO Kitt Peak magnetograms. The polar reversals during cycles 21 and 22 were linked to a small number of long-lived (1-year) activity complexes, whereas later reversals have been due to the cumulative trailing flux bias of numerous active regions.

With NSO colleagues Luca Bertello and Alexei Pevtsov, Petrie showed that variances in synoptic magnetogram measurements, due to both measurement errors and solar magnetic evolution, can impact extrapolated field models for the solar atmosphere. A paper led by Bertello appeared in *Solar Physics*.

<u>Service</u>

Petrie developed software that simulates poorly observed and unobserved fields at polar solar latitudes. This work has been applied to GONG and SOLIS synoptic maps that have appeared on the NISP Web site. With NSO programmer Tom Wentzel, Petrie corrected a graphical error in the potential field modeling products. As in the past, Petrie mentored REU/SRA students in 2013 and 2014 (see research results). D. Seligman's project appeared in *The Astrophysical Journal* this year and S. Ettinger's project is being extended and prepared for publication. Petrie has provided NSO data user support on accessing and applying NSO magnetogram data for various users including AFRL, NASA/CCMC, NOAA/SWPC, Predictive Science, U. Michigan, as well as users in Europe. Petrie refereed manuscripts for the *The Astrophysical Journal, Astronomy and Astrophysics, Solar Physics* and the *Journal of Geophysical Research*.

Alexei A. Pevtsov, Astronomer

<u>Areas of Interest</u>

Solar magnetic fields: topology, evolution, helicity, vector polarimetry; corona: coronal heating, xray bright points, coronal holes; sunspots: topology, evolution, Evershed flow, penumbral fine structure; space weather: solar drivers; chromosphere: filaments and prominences, Moreton waves; solar-stellar research.

Recent Research Results

A. Pevtsov studied solar (longitudinal and vector) magnetic fields, the role of magnetic gradient across magnetic neutral lines in the formation of chromospheric filaments, magnetic counterparts of coronal bright points, magnetic helicity and active region tilt (Joy's law), and properties of the photospheric and chromospheric Sun-as-a-star spectra. Both NSO and non-NSO (e.g., HMI, Mount Wilson Observatory) data were used in these studies. He also worked on improvements to the data reduction for observations taken by SOLIS. Comparison of solar disk integrated (SOLIS/ISS) and disk-resolved (SOLIS/VSM) spectra of the Ca II 854.2 nm chromospheric spectral line was used to evaluate the ability to derive some disk-resolved information about solar activity (e.g., fraction of solar disk covered by plage) from disk-integrated spectra. The model derived on the basis of solar data can then be used to interpret stellar observations. Dr. Pevtsov's role in demonstrating the value of the SOLIS data and increasing the productivity of this instrument was recognized by the 2014 AURA Science award.

Future Research Plans

Pevtsov plans to continue his research on properties and evolution of magnetic fields on the Sun and heliosphere. As a long-term goal, this research aims at understanding how magnetic fields are created by the global and local dynamos, how the magnetic field evolves as it travels through different layers of solar atmosphere and to the Earth orbit, how magnetic fields of localized features interact with each other, forming a large-scale field of the Sun, and how magnetic fields decay. He plans to continue studies of the Sun-as-a-star using SOLIS/ISS data, including adding a solar-stellar component. Pevtsov plans to spend a portion of his research time on studies related to the NSO synoptic program including development of new data products based on SOLIS and GONG magnetograms.

<u>Service</u>

A. Pevtsov is the Solar Atmosphere Program Scientist for the NSO Integrated Synoptic Program (NISP). In that capacity, he coordinates and leads the research and data analysis efforts by NSO scientists, postdocs, and scientific programmers associated with the program (which includes SOLIS and GONG projects). Pevtsov reviewed proposals for NASA and NSF and served as a reviewer for several professional publications. He supervises the NSO/SP technical library, chairs the NSO's Scientific Personnel Committee (SPC), and is a member of telescope allocation committees for NSO/SP and SOLIS. He serves on the Users' Committee for HAO's Mauna Loa Solar Observatory, the Math and Science Advisory Council (MSAC) for New Mexico State's Public Education Department, and the Advisory Board for the Historical Archive of Sunspot Observations (HASO) at the University of Extremadura (Spain). He is the chair for the International Astronomical Union (IAU) Working Group on Coordination of Synoptic Observations of the Sun and the vice-chair for the IAU Inter-Division Working Group on Solar-Type Stars. He co-organized one NSO workshop and served as co-editor for two conference proceedings.

Kevin Reardon, NSO Data Center Scientist

<u>Areas of Interest</u>

Dynamics and structure of the solar chromosphere; implementation of modern techniques for data archiving, processing, and discovery; innovative application of imaging spectroscopy techniques; post-focus instrumentation development; spectropolarimetry of the solar atmosphere; studies of inner planets and comets.

Recent Research Results

K. Reardon has recently been working with Philip Judge (HAO) and Gianna Cauzzi (INAF/Arcetri) on trying to understand the nature of the fine-scale, highly dynamic structures in the solar chromosphere. The high temporal and spatial resolution data obtained with IBIS show changes along extended fibrils occurring on timescales of just a few seconds, difficult to reconcile with magnetohydrodynamic evolution in the chromospheric plasma. Reardon and colleagues published a paper in *The Astrophysical Journal* detailing the appearance and occurrence rates of these features in different chromospheric spectral lines.

K. Reardon also has recently published a paper with Na Deng (NJIT) and other co-authors looking at the nature of rapid-blueshift-events (RBE) in the solar atmosphere as observed with IBIS and *Hinode*/SP. The statistical analysis of the dynamic chromospheric events and photospheric

magnetic interactions failed to show the expected correlation, raising questions about the relationship between these two phenomena.

Future Research Plans

K. Reardon will work on the application of new methods for processing the challenging volumes of data to be obtained with the DKIST. This will include techniques for calibrating and classifying the contents of those data, as well as data distribution channels, including the Virtual Solar Observatory, that support data discovery by the community.

K. Reardon will continue to work with Philip Judge and others in seeking a better understanding of the small-scale behavior of the solar chromosphere. This will involve observations pushing the current limits in temporal and spatial scales, coupled with the novel data from the Interface Region Imaging Spectrograph (IRIS).

K. Reardon is also Co-PI on a project with Fabio Cavallini and Vincenzo Greco (INAF/Arcetri) to develop an exploratory design for a tunable narrowband filter in the near-infrared (0.9-1.6 microns) for DKIST. This design, to be delivered in the coming year, is for a compact dual Fabry-Perot system that would permit diffraction-limited observations over a 90-arcsecond field-of-view.

<u>Service</u>

As the NSO Data Center Scientist, Reardon is suggesting ideas for the needs and approaches for processing and archiving of the data from the DKIST, as well as for the implementation of a modern data center deploying advanced analysis techniques in support of NSO's mission.

Reardon has developed tools that allow the solar community to locate and access datasets of interest from the Dunn Solar Telescope. The system, which generates summaries of the data obtained at the DST and provides quick-look Web pages., has been deployed for the three service-mode observing periods at the DST.

K. Reardon continues to support IBIS as a community instrument, providing guidance to users, software support, and ongoing improvements to the systems. He was one of the leads in providing supporting observations from the DST for the Hi-C, EUNIS, and VERIS, and VAULT sounding rocket launches from NASA's White Sands Missile Range, as well as for the coordinated observations with the IRIS mission.

Thomas R. Rimmele, Astronomer

Areas of Interest

Sunspots; penumbra; small-scale magnetic fields; active region dynamics; flares; acoustics waves; weak fields; adaptive optics; multi-conjugate adaptive optics; instrumentation.

Recent Research Results

As DKIST Associate Director with responsibility for the construction of the \$344M DKIST as well as the ramp up to full operations of DKIST in 2019, Rimmele's time is fully committed to the extensive management, organizational and service tasks. However, Rimmele maintains a strong interest in the development of AO technology. He guided a graduate student who developed a limb AO system capable of locking on H-alpha prominence structure, and he supervises a postdoc and assistant scientist who both are working on developing multi-conjugate adaptive optics for the Sun. In 2014 Rimmele co-authored ten publications.

Future Research Plans

T. Rimmele hopes to continue his efforts to perform observations at the highest spatial resolution adaptive optics in order to study the properties and the dynamics of small-scale magnetic elements. He plans to participate in the DKIST first-light observations with the primary objective of verifying the DKIST facility and instrumentation for science use on behalf of the community. He plans to actively engage in the execution of a number of Critical Science Plan experiments during early operations of DKIST. He will continue to improve the understanding of structure and dynamics of sunspots and test existing MHD models.

<u>Service</u>

Rimmele is NSO Associate Director for the DKIST. He mentors students and postdocs, supervises key NSO staff members and works closely with the DKIST Science Working Group and its chair. Rimmele participates in the European Association for Solar Telescopes (EAST) council meetings as DKIST representative with the goal of identifying potential collaborative efforts between DKIST and the European Solar Telescope (EST); he also is the NSO contact for SOLARNET. He guides the NSO multi-conjugate adaptive optics development effort, which is in collaboration with BBSO and KIS, Freiburg. He continues to serve as referee of a number of papers submitted to astrophysical and technical journals.

Dirk Schmidt, DKIST Postdoctoral Fellow

<u>Areas of Interest</u>

Adaptive optics, high spatio-temporal resolution observation techniques; development of adaptive optics systems, in particular multi-conjugate adaptive optics (MCAO) systems.

Recent Research Results & Future Research Plans and Service

D. Schmidt collaborates with the New Jersey Institute of Technology Big Bear Solar Observatory (NJIT/BBSO) and leads the development of the New Solar Telescope (NST) MCAO system, which is a pathfinder for a DKIST MCAO system. The NST system, which is a joint project of NSO and BBSO, has been installed and the first engineering runs have been performed. NST MCAO experiments will be conducted and analyzed, and upgrades of the system are planned.

Dr. Schmidt is also a collaborator on the development of MCAO control systems at the Kiepenheuer Institute for Solar Physics (KIS), and he supports MCAO experiments at the Gregor Telescope. His experimental solar MCAO development collaboration at KIS as a joint DKIST effort is ongoing.

*Sushanta C. Tripathy, Associate Scientist

Areas of Interest

Multi-wavelength helioseismology; sub-surface flows; global and local helioseismology; solar activity cycle; ocillations in solar flares.

Recent Research Results

Using simultaneous measurements of various observables at different heights in the solar atmosphere, S. Tripathy and collaborators have analyzed both GONG and HMI velocity and intensity data during two different periods of low and high solar acitivity. Using a model based on a coherent signal of p-modes, correlated and uncorrelated backgrounds and an incoherent noise

component, they have obtained estimates of oscillation mode parameters. It is found that the mode frequencies derived from this simultaneous fitting procedure are lower than those derived using an asymmetrical profile to the velocity time series. Additionally, they found that the mode frequencies show a clear solar cycle variations while mode amplitudes and line widths do not show the obvious variation with solar activity. It is planned to extend this analysis to more epochs.

S. Tripathy has investigated the sensitivity of the inferred subsurface flows using multiwavelength observables from HMI and AIA. Tripathy has also compared the surface flows derived from local correlation tracking with those from ring-diagram analysis just beneath the surface and find a strong correlation between the two flows. This indicates that despite the absorption of acoustic power in active regions, the flows calculated using helioseismic technique of ring-diagram is reliable.

S. Tripathy has continued the investigation of variations of the high degree mode frequencies. Analyzing the GONG data over a period of more than 13 years, it is shown that the frequency shifts measured relative to the spatial average over the solar disk is strongly correlated with the local magnetic field strength in contrast to the weak correlation observed during the extended minimum period. Analyzing the shifts in northern and southern hemispheres separately, he found that the localized mode frequencies also follow the hemispheric activity quite well.

Future Research Plans

Using data from AIA and HMI for multi-wavelength seismology, Tripathy will compare acoustic power within the context of formation height and phase and coherence relationships. He also plans to understand the driving mechanism for the global oscillation frequencies by comparing two different solar cycles, Solar Cycle 23 and 24. He also plans to extend the analysis of quasi-biennial periodicity seen in oscillation mode frequencies to other mode parameters e.g., line widths and amplitudes to understand the mechanism that drives this additional periodicity. Tripathy intends to extend the analysis of simultaneous fitting procedure to cover more epochs.

<u>Service</u>

S. Tripathy organizes the monthly synoptic science meeting at NSO. In recent past, he has been a reviewer for research proposals from abroad.

Alexandra Tritschler, Associate Scientist

Areas of Interest

Operational modes of large facilities; tools used by the users and operators of such facilities. Highresolution spectroscopy and spectropolarimetry of the photosphere and chromosphere; solar magnetic fields; fine-structure of sunspots, simulations of the influence of atmospheric turbulence and instrumentation on solar observations; post-focus instrumentation.

Current and Future Research Plans

A. Tritschler's main science interests have been focused on the high-resolution (spectral, spatial and temporal) aspects of solar physics and the fine structure of sunspots and pores in particular. She intends to pursue this interest further, employing IBIS (as well as FIRS and SPINOR) to determine the properties of photospheric and chromospheric layers of active regions and to infer their three-dimensional dynamic and magnetic structure and to compare those results to forward modeling. Tritschler will continue to investigate Service Mode Operations in solar physics using the Dunn Solar Telescope as a test bed for the DKIST.

<u>Service</u>

Tritschler is the DKIST's Operational Scientist and as such leads the development effort of operational concepts for the DKIST. She is responsible for the development and specification of tools to be used to efficiently operate the DKIST. Tritschler leads the Service Mode Operations effort of the Dunn Solar Telescope in preparation for the DKIST. Service Mode Operations of the DST are offered currently twice per year to the international community. Tritschler has been mentoring numerous summer REU and SRA students and is a member of the Sacramento Peak telescope allocation committee for the Dunn Solar Telescope. She is also the colloquium organizer in Sunspot and was/is actively involved in the organization of workshops (as an SOC member) and sessions at the IAU, AAS/SPD, and AGU. Tritschler has served on proposal panel reviews and has been a reviewer of publications for the Astrophysical Journal Letters, Astrophysical Journal, Astronomy and Astrophysics, Solar Physics, and Astronomical Notes.

Han Uitenbroek, Astronomer

<u>Areas of Interest</u>

Radiative transfer modeling and structure and dynamics of the solar atmosphere; modeling and measurement of polarized light and interpreting observations.

Recent Research Results

H. Uitenbroek continues to work on expanding and improving his multi-dimensional numerical radiative transfer code RH. The RH code has been made available to the community from the start and is widely used by the solar community and, in some cases, even outside that. The RH code has been used to calculate Mg II spectra from Rad-MHD simulations of solar chromospheric dynamics in preparation for the launch of the IRIS mission. The results have been published in three *ApJ* papers that have been released recently. The code has also been used by Adam Kowalski (NASA GSFC) to model flare spectra in M-dwarfs, by Holtzeuter (MPS Lindau) et al. to model non-LTE iron line spectra in 3D, and by Nelson et al. to model Ellerman bomb spectra in hydrogen and iron lines. Together with E. Mallorca (Perugia, Italy), Uitenbroek has used the code to determine the solar fluorine abundance. With NSO colleague Serena Criscuoli, Uitenbroek developed a novel method to accurately measure the temperature gradient in the solar atmosphere at high spatial resolution using opacity-conjugate wavelengths. The ultimate goal is to implement this method in a satellite mission being developed by the Laboratory for Atmospheric and Space Physics (LASP) in Boulder, and to use it to refine modeling of spatially resolved solar irradiance. Together, they also worked on characterizing the center-to- limb variations of irradiance due to small-scale magnetic elements. With CU undergraduate Christopher Moore, S. Criscuoli and researchers at CU and LASP in Boulder, Uitenbroek investigated the effects of local dynamogenerated magnetic fields on abundance determinations of oxygen and iron.

Future Research Plans

Development and maintenance of the RH code will continue. Concentration will be on the contribution to irradiance at different wavelengths from small-scale magnetic elements, forward modeling of polarized Sunspot spectra, and forward modeling of polarized radiation from chromospheric structures, both from state-of-the-art 3D Rad-MHD simulations. Uitenbroek will also undertake analysis of IRIS spectra and comparison of its spectra with forward modeling of the Mg II lines.

<u>Service</u>

Uitenbroek is the program scientist for the Dunn Solar Telescope at Sac Peak. In addition, he serves as chair of the Sac Peak Telescope Allocation Committee, leads the IT department in Sunspot, and is part of the NSO Scientific Personnel Committee (SPC). With Alexandra Tritschler, Uitenbroek leads the REU/RET effort at Sacramento peak. He actively supports users of the RH code with updates and helps with running the code. He is Co-I on the IRIS SMEX proposal by Lockheed that was launched by NASA in June 2013. The RH code is provided on the IRIS data distribution Web page for downloading. Uitenbroek is also member of the planning working group for the next Japanese solar satellite Solar C. He regularly serves as referee for papers and on review panels for proposals. He is currently the Site Leader for Sacramento Peak.

Fraser Watson, Postdoctoral Research Associate

<u>Areas of Interest</u>

Long-term sunspot properties; changes in the solar cycle; automated image processing; synoptic data analysis; spectro-polarimetric analysis of sunspot data; data calibration techniques.

Recent Research Results

F. Watson's most recent research results come from a cross-calibration study undertaken at two NSO facilities to determine whether certain observing programs could be improved by using more instrumentation. This study has shown that replicating McMath-Pierce Solar Telescope infrared sunspot measurements at the Dunn Solar Telescope is not only possible, but beneficial due to the increased spatial resolution available with the FIRS instrument. An article detailing these results is under-going internal review at NSO before submission to a journal in the near future.

<u>Future Research Plans</u>

Watson plans to analyze the efficiency and accuracy of data calibration methods for the first generation suite of DKIST instrumentation as part of the DKIST Data Center team.

<u>Service</u>

F. Watson assists in the synoptic observing program at the McMath-Pierce Solar Telescope, and recently assisted in the service-mode observing program at the Dunn Solar Telescope, as well as running a study to cross-calibrate data between the two facilities. Over the past year, he has represented NSO at nine public outreach events. He is currently serving as an editor of a topical issue in the *Journal of Space Weather and Space Climate*. The STARA sunspot catalogue is now used regularly within the field and regular requests are received for help in using the data. In some cases, people have referred to it as the 'NSO sunspot catalogue' when asking about it.

Friedrich Wöger, Associate Scientist

Areas of Interest

Image reconstruction techniques; adaptive optics; two-dimensional spectroscopy, and spectropolarimetry; DKIST visible broadband imager (VBI); DKIST data handling system (DHS).

Recent Research Results

F. Wöger has been working on a theory to compute the transfer function of Earth's turbulent atmosphere and the adaptive optics system directly from data delivered by the adaptive optics system. This is important to achieve high photometric precision in images reconstructed using

speckle reconstruction algorithms. He is currently working on a theory that extends the validity of the transfer function models to very large field of views.

Wöger has tested VBI components not only at the Boulder laboratory, but also at the Dunn Solar Telescope in Sunspot, New Mexico, to determine compliance with the requirements of the VBI. In particular, this involved the complicated VBI interference filters that have been analyzed for performance. The results of these tests were recently published.

Future Research Plans

Dr. Wöger is planning to work on improved methods for image reconstruction for data acquired with 2D spectroscopic and spectro-polarimetric instruments, such as DKIST VTF data. These algorithms will be based on speckle interferometry and allow the acquisition of data at diffraction-limited resolution. He continues to work on developing accurate models for atmospheric transfer functions, and is interested in investigating expanding current models for use with multi-conjugate adaptive optics systems.

<u>Service</u>

Wöger is the DKIST instrument systems scientist, and as such, is the scientific interface between the DKIST project and the partner institutes that build instruments for DKIST. He is involved in the DKIST VBI instrument effort as its principal investigator, and is overseeing its construction at NSO Boulder. Furthermore, as the DKIST Data Handling Scientist, he is supervising the DKIST data handling system development, ensuring the proper documentation and implementation of the requirements defined for the system and creating a complete data model for DKIST. In his function as the DKIST Wavefront Correction Scientist, Wöger is guiding the DKIST WFC team towards a Critical Design Review by reviewing all WFC documentation that describes derived design requirements and the design itself. He also has a role in the optical design effort for the wavefront sensors.

Woeger has been supporting supervision of a CU masters student in Computer Engineering in summer 2014 as part of an effort to implement a subset of the VBI speckle interferometry algorithms. He is currently co-supervising a CU graduate student in the modeling of optical transfer functions of Earth's turbulent atmosphere. Woeger has been giving several invited talks over the course of 2014, at the High Altitude Observatory, the Big Bear Solar Observatory, and the Kipenenheuer Institut für Sonnenphysik.

APPENDIX I: ACRONYM GLOSSARY

A&E	Architecture and Engineering
ADAPT	Air Force Data Assimilative Photospheric flux Transport
AFRL	Air Force Research Laboratory
AFWA	Air Force Weather Agency
AIA	Atmospheric Imaging Assembly (SDO)
AISES	American Indian Science and Engineering Society
aO	Active Optics
AO	Adaptive Optics
AR	Active Region
ARRA	American Recovery and Reinvestment Act
ASP	Advanced Stokes Polarimeter
ATI	Advanced Technology Instrumentation (NSF)
ATM	Atmospheric Sciences (Division of NSF)
ATRC	Advanced Technology Research Center (University of Hawai'i)
ATST	Advanced Technology Solar Telescope
AURA	Association of Universities for Research in Astronomy, Inc.
AWI	Akamai Workforce Initiative (Hawaiʻi)
BABO	Baboquivari Instrument (NSO McMath-Pierce Solar Telescope)
BLNR	Bureau of Land and Natural Resources
BBSO	Big Bear Solar Observatory
CAM	Cost Account Manager (DKIST)
CCMC	Community Coordinated Modeling Center
CD-ROM	Compact Disk – Read Only Memory
CDR	Critical Design Review
CDUP	Conservation District User Permit
CfA	Center for Astrophysics (Harvard Smithsonian)
CfAO	Center for Adaptive Optics
CGEP	Collaborative Graduate Education Program (University of Colorado, Boulder)
CHU	Critical Hardware Upgrade
CISM	Center for Integrated Space Weather Modeling
CLEA	Contemporary Laboratory Exercises in Astronomy
CMEs	Coronal Mass Ejections
CNC	Computer Numerical Controlled
CoDR	Conceptual Design Review
CoRoT	COnvection ROtation and planetary Transits (French Space Agency CNES)
CoSEC	Collaborative Sun-Earth Connection
CR	Carrington Rotation
•	Cryogenic Near-IR Spectro-Polarimeter (DKIST)
CSF	Common Services Framework
CSIC	Consejo Superior de Investigaciones Científicas (Spain)
CSP	Critical Science Plan
CU	University of Colorado, Boulder
CYRA	Cryogenic Infrared Spectrograph (NJIT, Big Bear Solar Observatory)

DA	Diversity Advocate
DB-P	Dual-beam Polarizer (McMath-Pierce Telescope)
D&D	Design & Development
DASL	Data and Activities for Solar Learning
DC	Data Center
DEIS	Draft Environmental Impact Statement
DEM	Differential Emission Measure
DHS	Data Handling System
DKIST	Daniel K. Inouye Solar Telescope (formerlyATST)
DL-NIRSP	Diffraction-Limited Near-Infrared Spectropolarimeter (DKIST)
DLSP	Diffraction-Limited Spectro-Polarimeter
DLT	Digital Linear Tape
DM	Deformable Mirror
DMAC	Data Management and Analysis Center (GONG)
DoD	Department of Defense
DRD	Design Requirements Document
DRMS	Decision, Risk and Management Sciences (NSF)
DST	Dunn Solar Telescope
EAST	European Association for Solar Telescopes
EGSO	European Grid of Solar Observations
EIS	Environmental Impact Statement
EIT	Extreme ultraviolet Imaging Telescope (SOHO)
EPO	Educational and Public Outreach
ESF	Evans Solar Facility
EST	European Solar Telescope
ETS	Engineering and Technical Services (NOAO)
FDP	Full-Disk Patrol (SOLIS)
FDR	Final Design Review
FEIS	Final Environmental Impact Statement
FIRS	Facility Infrared Spectropolarimeter
FLC	Ferroelectric Liquid Crystal
FOV	Field of View
FPGA	Field Programmable Gate Array
FTEs	Full Time Equivalents
FTS	Fourier Transform Spectrometer
FY	Fiscal Year
GB	Giga Bytes
GNAT	Global Network of Astronomical Telescopes, Inc. (Tucson)
GOES	Geostationary Operational Environmental Satellites (NASA and NOAA)
GONG	Global Oscillation Network Group
GSFC	Goddard Space Flight Center (NASA)
GUI	Graphical User Interface
HAO	High Altitude Observatory
HMI	Helioseismic and Magnetic Imager
HO	Haleakalā Observatory

HOAO	High Order Adaptive Optics
HR	Human Resources
HSG	Horizontal Spectrograph
HXR	
IAA	Hard X-Ray
	Instituto de Astrofísica de Andalucía (Spain)
IAC	Instituto de Astrofísica de Canarias (Spain)
IBIS	Interferometric BIdimensional Spectrometer (Arcetri Observatory)
ICD	Interface Control Document
ICM	Inversion by Central Moments
ICS	Instrument Control System
IDL	Interactive Data Language
IfA	Institute for Astronomy (University of Hawai`i)
IFU	Integrated Field Unit (McMath-Pierce Solar Telescope Facility)
IHY	International Heliophysical Year
IMaX	Imaging Magnetograph eXperiment (SUNRISE)
IR	Infrared
IRES	International Research Experience for Students (NSF)
IRIS SMEX	Interface Region Imaging Spectrograph Small Explorer Mission (NASA)
ISOON	Improved Solar Observing Optical Network (now O-SPAN)
ISP	Integrated Synoptic Program (NSO)
ISS	Integrated Sunlight Spectrometer (SOLIS)
IT&C	Integration, Testing, & Commissioning
KAOS	Kiepenheuer Adaptive Optics System
KCE	KC Environmental (Maui)
KIS	Kiepenheuer Institute for Solar Physics (Freiburg, Germany)
KPNO	Kitt Peak National Observatory
KPVT	Kitt Peak Vacuum Telescope
LAPLACE	Life and PLAnets Center (University of Arizona)
LASP	Laboratory for Atmospheric and Space Physics (University of Colorado, Boulder)
LCROSS	Lunar CRater Observation and Sensing Satellite
LESIA	Laboratoire d'études patiales et d'instrumentation en astrophysique (Paris Observatory)
LMSAL	Lockheed Martin Solar and Astrophysics Laboratory
LoHCo	Local Helioseismolgy Comparison Group
LRP	Long Range Plan
LTE	Local Thermodynamic Equilibrium
LWS	Living With a Star
MBP	Magnetic Bright Point
McMP	McMath-Pierce
MCAO	Multi-Conjugate Adaptive Optics
MCC	Maui Community College
MDI	Michelson Doppler Imager (SOHO)
ME	Milne-Eddington
MEDB	Maui Economic Development Board
MEDB	Magnetohydrodynamic
MKIR	Magnetonydrodynamic Mauna Kea Infrared

MREFC	Major Research Equipment Facilities Construction (NSF)
MRI	Major Research Instrumentation (NSF)
MSAC	Math and Science Advisory Council (State of New Mexico)
MSFC	Marshall Space Flight Center (NASA)
MWO	Mt. Wilson Observatory (California)
NAC	NSO Array Camera
NAI	NASA Astrobiology Institute
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NASM	National Air and Space Museum
NCAR	National Center for Atmospheric Research
NDSC	Network for the Detection of Stratospheric Change
NHPA	National Historic Preservation Act
NHWG	Native Hawaiian Working Group
NIR	Near Infrared
NISP	NSO Integrated Synoptic Program
NJIT	New Jersey Institute of Technology
NLFFF	Non-Linear Force-Free Field
NLTE	Non-Local Thermodynamic Equilibrium
NMDOT	New Mexico Department of Transportation
NOAA	National Oceanic and Atmospheric Administration
NOAO	National Optical Astronomy Observatory
NPDES	National Pollutant Discharge Elimination System
NPFC	Non-Potential Field Calculation
NRC	National Research Council
NSBP	National Society of Black Physicists
NSF	National Science Foundation
NSF/AST	National Science Foundation, Division of Astronomical Sciences
NSF/ATM	National Science Foundation, Division of Atmospheric Sciences
NSHP	National Society of Hispanic Physicsts
NSO	National Solar Observatory
NSO/SP	National Solar Observatory Sacramento Peak
NSO/T	National Solar Observatory Tucson
NST	New Solar Telescope (NJIT Big Bear Solar Observatory)
NWNH	New World New Horizons (Astro2010: Astronomy & Astrophysics Decadal Survey)
NWRA/CoRA	NorthWest Research Associates/Colorado Research Associates
O&M	Operations and Maintenance
OCD	Operations Concept Definition Document (DKIST)
OCS	Observatory Control System
OMB	Office of Management and Budget
O-SPAN	Optical Solar Patrol Network (formerly ISOON)
PAARE	Partnerships in Astronomy & Astrophysics Research & Education (NSF)
PAEO	Public Affairs and Educational Outreach (NOAO)
PCA	Principal Component Analysis
PDR	Preliminary Design Review

PI	Principal Investigator
PMCS	Project Management Control System
ProMag	PROminence Magnetometer (HAO)
PSPT	Precision Solar Photometric Telescope
QA/QC	Quality Assurance/Quality Control
QBP	Quasi-Biennial Periodicity
QL	Quick-Look
QSA	Quasi-Static Alignment
QU	Queen's University (Belfast, Ireland, UK)
RA	Resident Astronomer
RASL	Research in Active Solar Longitudes
RDSA	Reference Design Studies and Analyses
RET	Research Experiences for Teachers
REU	Research Experiences for Undergraduates
RFP	Request for Proposal
RHESSI	Reuven Ramaty High Energy Solar Spectroscopic Imager (NASA)
RISE/PSPT	Radiative Inputs from Sun to Earth/Precision Solar Photometric Telescope
RMS	Root-Mean-Square
ROD	Record of Decision
ROSA	Rapid Oscillations in the Solar Atmosphere
SACNAS	Society for the Advancement of Chicanos an Native Americans in Science
SAN	Storage Area Network
SASSA	Spatially Averaged Signed Shear Angle
SCB	Sequential Chromospheric Brightening
SCOPE	Southwest Consortium of Observatories for Public Education
SDO	Solar Dynamic Observatory
SDR	Solar Differential Rotation
SFC	Space Flight Center (NASA)
SH	Spherical Harmonic
SMO	Service-Mode Operations
S&O	Support and Operations (DKIST)
SOC	Solar Observatory Council (AURA)
SOHO	Solar and Heliospheric Observatory
SOI	Solar Oscillations Investigations (SOHO)
SOLIS	Synoptic Optical Long-term Investigations of the Sun
SONG	Stellar Oscillation Network Group
SOT	Solar Optical Telescope
SOT/SP	Solar Optical Telescope Spectro-Polarimeter (Hinode)
SOW	Statement of Work
SPINOR	Spectro-Polarimeter for Infrared and Optical Regions
SPD	Solar Physics Division (AAS)
SPRING	Solar Physics Research Integrated Network Group (European Union)
SPSC	Space Science Center (University of Colorado, Boulder)
SRA	Summer Research Assistant
SRD	Science Requirements Document
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WCCSWavefront Correction Control SystemWDCWorkforce and Diversity Committee (AURA)WFCWavefront Correction (DKIST)	VTF	Visible Tunable Filter (DKIST)
WDCWorkforce and Diversity Committee (AURA)WFCWavefront Correction (DKIST)	WBS	Work Breakdown Structure
WFC Wavefront Correction (DKIST)	WCCS	Wavefront Correction Control System
	WDC	Workforce and Diversity Committee (AURA)
	WFC	Wavefront Correction (DKIST)
1	WHI	Whole Heliospheric Interval
WSA Wang-Sheeley-Arge (Solar Wind Model)		
		Web Service Description Language
	WWW	World Wide Web
WSDL Web Service Description Language		1 0 0
1 0 0		