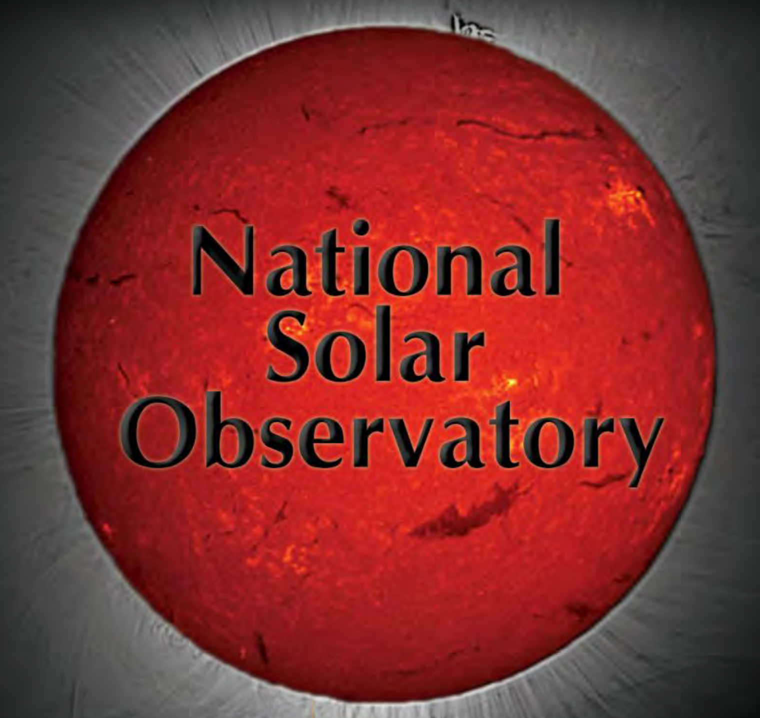


National Solar Observatory

NSO

FY 2016

Annual Progress Report &

FY 2017

Annual Program Plan

Submitted to the National Science Foundation under Cooperative Agreement No. 0946422
and Cooperative Support Agreement No. 1400450

This report is also published on the NSO Web site: http://www.nso.edu

The National Solar Observatory is operated by the
Association of Universities for Research in Astronomy, Inc. (AURA) under
cooperative agreement with the National Science Foundation

MISSION

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

NSO accomplishes this mission by:

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

RESEARCH OBJECTIVES

The broad research goals of NSO are to:

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

This page intentionally left blank.

TABLE OF CONTENTS

This page intentionally left blank.

1 EXECUTIVE SUMMARY

The National Solar Observatory (NSO) is the primary provider of key ground-based solar facilities to the US solar community. NSO makes available to the community 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 Program includes the Synoptic Optical Long-term Investigation of the Sun (SOLIS) and the Global Oscillation Network Group (GONG). Developing partnerships to establish a concept for a future network (SPRING) that replaces GONG and SOLIS and provides ground-based solar data adapted to the demands of Space Weather modeling.
- 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 has its headquarters (HQ) collocated with the University of Colorado, Boulder (CU-Boulder). The Boulder HQ hosts the DKIST and NISP Data Centers.
- Developing the DKIST operations team and the Remote Office Building (ROB) in Maui.

In parallel with these major components, NSO will continue:

- Developing the adaptive optics (AO), multi-conjugate AO (MCAO), and infrared (IR) technology needed for the DKIST.
- Expanding interagency collaborations for NISP following the guidance in the National Space Weather Strategy and Action Plan.
- Upgrading the GONG network to adapt it to the needs of the Space Weather research community, ensuring its competitive continuation for another solar cycle.
- Operating the Dunn Solar Telescope (DST) and maintaining its competitiveness through AO and state-of-the-art instrumentation.
- Helping the transition of operations of the DST to a consortium led by New Mexico State University (NMSU) in FY 2018. Planning for the discontinuation of operations of the McMath-Pierce Solar Telescope (McMP) in a timely fashion to meet the NSF mandate.
- Increasing diversity of the solar workforce.

Some of the programmatic highlights of the NSO Program in FY 2017 include:

- Continuation of DKIST construction on Haleakalā. In FY 2017, the Telescope Mount Assembly installation will move forward in preparation for the acceptance tests in early FY 2018.
- Start the construction of the ROB in Pukalani near the UH/IfA facility.

- Enhance community participation in the DKIST Critical Science Plan (CSP) development with a series of workshops targeted to the creation of Science Use Cases containing detailed implementation plans. Continue forming the core teams for DKIST operations in Boulder and Maui, including the DKIST Data Center.
- Complete the SOLIS upgrade with the installation of the Full-Disk Patrol (FDP) tunable filter. Select a new site for SOLIS and relocate the facility to the new site.
- Consolidate funding partners for the operation of NISP, in particular with the NOAA/Space Weather Prediction Center (SWPC).
- Continue implementing NSO's transition plan that describes the relocation of the NSO HQ to CU-Boulder.
- Proceed with the second shared faculty position between CU and NSO.

A few of the major actions to advance solar physics that NSO will undertake in FY 2017 include:

- Proactively integrate NSO scientists in the CU-led George Ellery Hale fellowship program and ensure fluent interaction with the graduate students. Continue participating in the COLLAGE courses.
- Continue visits to US universities to publicize the DKIST project status and investigate potential partnerships.
- Promote international participation in DKIST.
- Continue consolidating NSO's Outreach Program by hiring Education and Public Outreach staff in Maui.
- Ensure NSO Programs' visibility during the 2017 eclipse activities, emphasizing DKIST science and capabilities.

In FY 2017, the anticipated observatory funding is $17.5M, split into $11.5M for the DKIST operations funding wedge and $6M for base-program operations that include activities in Sunspot and Tucson. This year, the relocation of NSO HQ to the CU-Boulder campus uses a decreasing fraction of the DKIST funding wedge to cover the costs of the move (see Section 9). NSO operations presence in New Mexico and Arizona ends in FY 2017. In Sunspot, NSO activities concentrate on operating the DST, which is still in high demand. In Tucson, most of the efforts focus on the upgrades of SOLIS and the preparations for its move to a new site.

In FY 2017, we will operate the DST under a similar model of reduced operation as implemented last year. In this model, a pool of three observers is shared with DKIST Operations and provides a total of 2 FTEs to support visiting astronomers at the DST. This reduced support from the traditional levels of 3 FTEs has forced the closure of the telescope during the weekends. The potential addition of NMSU personnel, and the required training in preparation for transfer of operations of the telescope in FY 2018, might impose changes to the scheduling of the facility. NSO and NMSU are continuing conversations to secure the proper transfer of expertise to the newly hired employees. NSO plans to support the development by NMSU of a more robust, easy to operate, AO system at the DST. Conversations are ongoing to evaluate potential interest of extended presence at the facility of critical

NSO employees as remote workers in FY 2018. This presence will facilitate a smoother transfer to NSMU as it will prolong the training period. In return, NSO will have access to an amount of observing time according to the cost guidelines used by the NMSU Consortium.

In Tucson, the NISP team continues with upgrades for the SOLIS suite of instruments and with operating the GONG engineering units. Most of the scientists are already based at Boulder HQ, and the activities in Arizona largely concentrate on technical aspects. Weekly meetings between the program scientists and technical staff at the two sites occur to discuss progress and to revise priorities as needed. The NISP Data Center team is collaborating with the NOAA/SWPC team on implementing the GONG Space Weather data processing pipelines. The relocation of the NISP Data Center infrastructure from Tucson to the Space Science Center (SPSC) building in Boulder will occur during the first quarter of FY 2017. The GONG engineering shelters will follow in the second quarter. In parallel, NISP will make significant progress on the two top priorities of the Program: the refurbishment of the GONG network and SOLIS relocation. Specific milestones in FY 2017 for GONG refurbishment are the testing of the new detectors and the acquisition, calibration, and deployment of new polarization modulators. For SOLIS, a final site will be selected in the first quarter of FY 2017. The preparations for the relocation of the facility and the actual move will occur during the remaining part of the year.

DKIST construction work continues on Haleakalā. After securing the water-tightness of the enclosure, work on the Telescope Mount Assembly will start in earnest. Acceptance of the Coudé platform will occur in mid-FY 2017. DKIST Operations will strongly concentrate on progressing with construction of the ROB and with the Data Center Design and Development reviews. The ROB has achieved significant milestones in FY 2016: the Environmental Assessment (EA) was successfully passed in the first half of that year and bids for the construction of the office building received. The cumulative delay of the ROB is over one year; therefore, the start of construction of this key facility is the top priority for the Observatory in FY 2017. The build up of the operations workforce will not progress at the pace described in the Cooperative Agreement until office space becomes available in Maui. In some cases, a different solution for the timely hiring of the operations workforce is possible. An example is the DLIST observers that are being trained at the DST before they relocate to Maui. In Boulder, the Data Center has made significant progress in defining the Scientific Requirements and the Operational Concept Definitions. In FY 2017, the Conceptual and Preliminary Design Reviews of the DKIST Data Center will take place. Science-wise, FY 2017 will see significant progress in the development of the Critical Science Plan (CSP). To this end, a series of community-led CSP workshops will start in FY 2017 and run through the latter part of FY 2018. The outcome of these workshops will include a set of science-use cases that easily translate to specific operational needs and implementation strategies for the DKIST.

NSO is already occupying the 3rd floor of the CU-Boulder SPSC building. As we settle into this new HQ, NSO will continue implementing, and updating as needed, the staffing plan developed by the top-level managers of the Observatory. A few personnel moves from Sunspot and Tucson to Boulder will still occur in FY 2017. Relocations to Maui will be on hold until the ROB becomes available (FY 2018). All of the infrastructure work required for the relocation of NSO will culminate with the move of the GONG engineering units from Tucson to the East Campus of CU-Boulder. The Observatory has joined the Boulder Solar Alliance's REU proposal submitted this year to the NSF. The proposal covers five years starting in FY 2017. NSO participation focuses on mentoring undergraduate students, primarily at our Boulder HQ, but also includes a component of activities in Maui.

NSO has reinvigorated our public outreach program in FY 2016 by hiring a Boulder-based Head of Education and Public Outreach (EPO). An assistant in Maui will complete our EPO team; the position has been advertised and will be filled soon after the start of FY 2017. The components of the new EPO Program of the Observatory are described in Section 7.

2017 is a special year for solar physics. A total solar eclipse will cross the country from Oregon to South Carolina. It is a unique opportunity to publicize the Sun, its corona and the understanding the DKIST will enable. NSO will develop a set of initiatives aiming at disseminating solar science nationwide. A series of monthly webinars will help provide the scientific content that the mass media demands to promote the event adequately. The Citizen Continental-America Telescopic Eclipse (CATE) experiment, led by NSO astronomer Matt Penn, will distribute several tens of amateur astronomers along the eclipse path and will create a data set of coronal observations with great scientific potential. Additional efforts to involve high schools and community colleges are currently ongoing.

Figure 1. *A vision for NSO over the next two decades is displayed. DKIST operations play a prominent role in parallel with an upgraded synoptic program starting a decade from now.*

NSO 2017 Program

- DKIST
  - Continue construction on Haleakalā.
  - Start construction of the Remote Office Building in Pukalani.
  - Review the scope of the DKIST Data Center. Conduct CoDR & PDR.
  - Further recruitment of national and international collaborations.
  - Continue development of first-light instrumentation in collaboration with partner institutions.
  - Organize the first series of Critical Science Plan workshops.
- NSO Integrated Synoptic Program (NISP)
  - Operate SOLIS and GONG.
  - Select a new site for SOLIS operations and relocate it.
  - Upgrade the GONG network hardware.
  - Develop partnerships for a future synoptic network.
  - Continue to seek outside funding for operations.
- Dunn Solar Telescope (all DKIST related activities)
  - Operate the facility in a reduced service support model.
  - Conduct PI observations for the solar community.
  - Train NMSU personnel in the operations of the facility.
- McMath-Pierce Solar Telescope (all DKIST related activities)
  - Continue IR observations.
  - Plan for the end of operations of the facility.
- New NSO Directorate Site and Staff Consolidation
  - Continue relocating staff according to the transition plan.
  - Open the second shared faculty position with CU Boulder.
  - Integrate NSO's scientists in the activities of the Hale Program.
- Education and Outreach and Broadening Participation
  - Promote NSO's programs during the 2017 Eclipse activities.
  - Train the next generation of solar astronomers (REU's, SRA's, thesis students, postdocs).
  - Hire a Maui-based EPO person.

Figure 2. *Planned and ongoing programs and projects at NSO.*

2 FY 2016 SCIENTIFIC RESEARCH & DEVELOPMENT HIGHLIGHTS

2.1 Vector Magnetic Field Measurements along a Cooled Stereo-Imaged Coronal Loop

The solar corona is a low beta, highly conducting magneto-plasma whose evolution is controlled by the magnetic field coupling it to the Sun and its connections to interplanetary space. Its fundamental magneto-thermal structure is poorly understood in part because remote measurements of the coronal field are very challenging. To date, the variation of the vector magnetic field along individual loops in the hot solar corona remains unmeasured. Using a unique combination of spectropolarimetry and stereoscopy, T. A. Schad (NSO) et al. (*ApJ*, 2016) infer and compare, for the first time, the vector magnetic field structure and three-dimensional morphology of an individuated coronal loop structure undergoing a thermal instability. Schad and colleagues analyze spectropolarimetric data of the He I 10830 Å triplet ($1s2s^3S_1 - 1s2p\ ^3P_{2,1,0}$) obtained at the Dunn Solar Telescope (DST) with the Facility Infrared Spectropolarimeter (FIRS) on 19 September 2011 (see Figure 2.1). Cool coronal loops are identified on the solar disk by their prominent drainage signatures in the He I data (redshifts up to 185 km sec^{-1}). Extinction of EUV background radiation along these loops is observed by both the Atmospheric Imaging Assembly (AIA) onboard the Solar Dynamics Observatory (SDO) and the Extreme Ultraviolet Imager (EUI) onboard spacecraft A of the Solar TErrestrial RElations Observatory (STEREO), and is used to stereoscopically triangulate the loop geometry up to heights of 70 Mm (0.1 R_{sun}) above the solar surface. The He I polarized spectra along this loop exhibit signatures indicative of atomic-level polarization induced by optical pumping as well as magnetic signatures through the Hanle and Zeeman effects. Spectropolarimetric inversions based on the advanced forward modeling of the HAZEL code indicate that the magnetic field is generally oriented along the coronal loop axis, thereby affirming the long-held assumption that coronal loops outline the coronal magnetic field. The derived height dependence of the magnetic field intensity above the active region lends credence to the few previous lower spatial resolution measurements of coronal field intensity via gyroresonant radio emission. The technique Schad and colleagues demonstrate is a powerful one that may help better understand the thermodynamics of coronal fine structure magnetism.

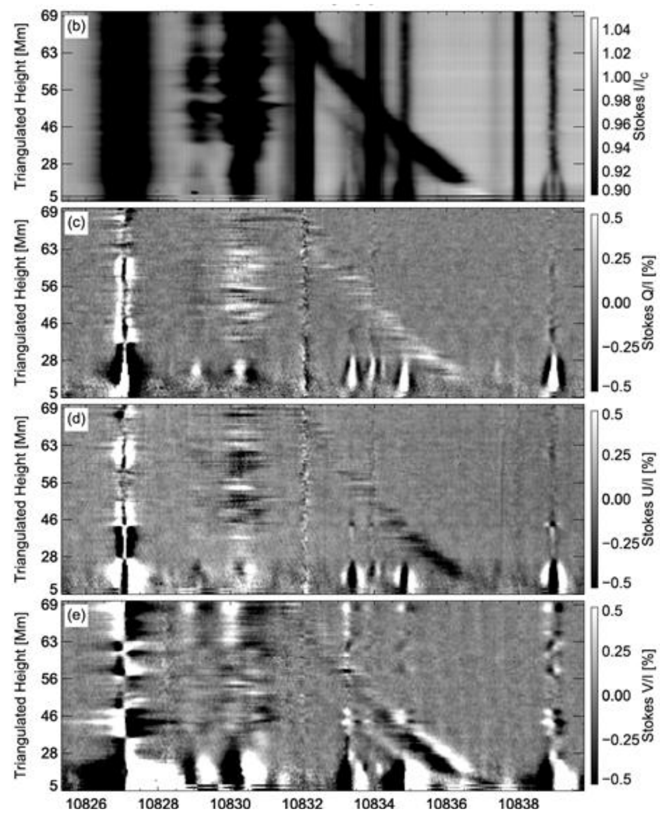


Figure 2.1. *Stokes spectral observations in the vicinity of the orthohelium triplet at 1083 nm extracted from a coronal loop undergoing a thermal instability. The ordinate axis indicates the stereoscopically determined height above the solar surface. The He I spectral feature exhibiting acceleration as a function of height originates from the coronal loop.*

2.2 The Possible Impact of L5 Magnetograms on Non-Potential Solar Coronal Magnetic Field Simulations

The proposed Carrington-L5 mission would bring instruments to the L5 Lagrange point to provide crucial data for space weather prediction. To assess the importance of including a magnetograph, M. Weinzierl (Durham U., UK) et al. (*ApJ* **828**, 2016) consider the possible differences in non-potential solar coronal magnetic field simulations when magnetograph observations are available from the L5 point, compared with an L1-based field of view (FOV). Weinzierl and colleagues constructed a timeseries of synoptic radial magnetic field maps to capture the emergence of two active regions from the L5 FOV. These regions are initially absent in the L1 magnetic field maps, but are included once they rotate into the L1 FOV. Non-potential simulations for these two sets of input data are compared in detail. Within the bipolar active regions themselves, differences in the magnetic field structure can exist between the two simulations once the active regions are included in both. These differences tend to reduce within 5 days of the active region being included in L1. The delayed emergence in L1 can, however, lead to significant persistent differences in long-range connectivity between the active regions and the surrounding fields, and also in the global magnetic energy. In particular, the open magnetic flux and the location of open magnetic footpoints, are sensitive to capturing the real-time of emergence. These results suggest that a magnetograph at L5 could significantly improve predictions of the nonpotential corona, the interplanetary magnetic field, and of solar wind source regions on the Sun.

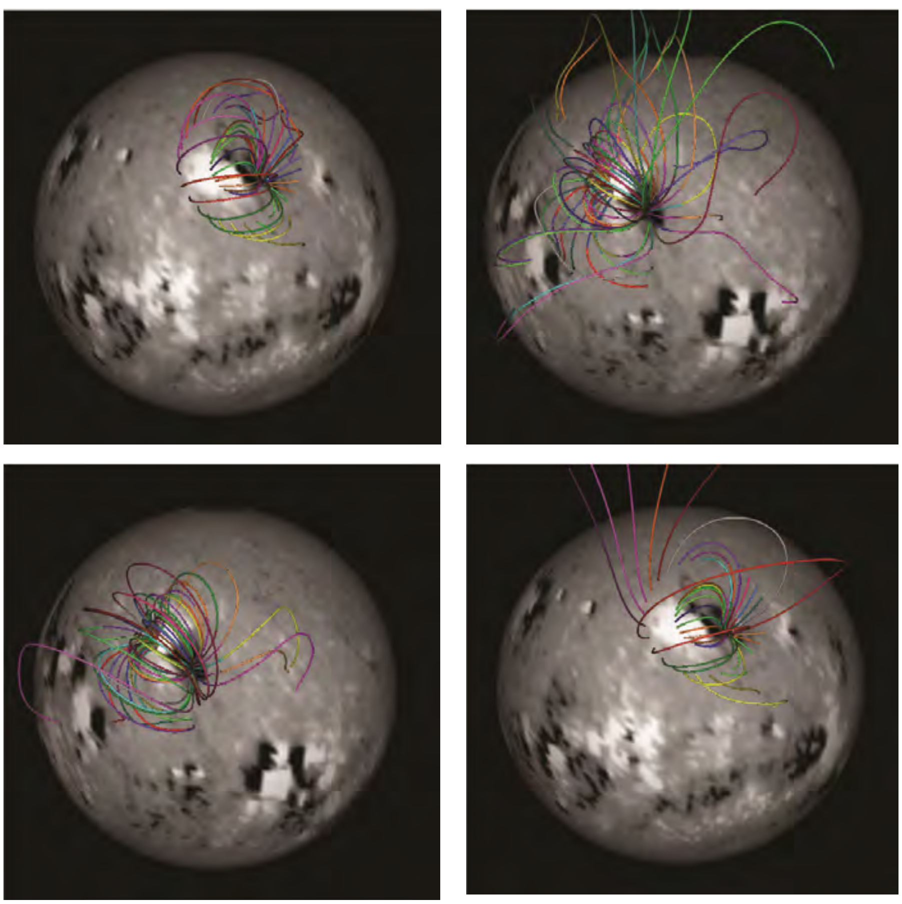
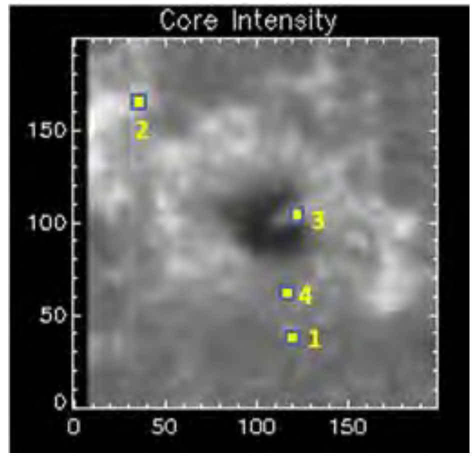


Figure 2.2. *Example of magnetic field lines (with random colors for identification) for the two active regions, each shown on a day when the active regions have completely rotated into the L1 FOV and are visible from both L1 and L5. The top row shows the simulation using the L1 data set, the bottom row shows the simulation using the L5 data set. The left column shows the appearance of the first active region on day 21 of the simulation, the right column shows the appearance of the second active region on day 36 of the simulation. While the photospheric field (shown in greyscales) is identical for the L1 and L5 case, there are obvious differences in the connectivity and structure of the coronal magnetic field.*

2.3 Magnetometry of the Solar Chromosphere: Recent Results from the SOLIS/VSM

The Synoptic Optical Long-term Investigations of the Sun, Vector SpectroMagnetograph (SOLIS/VSM) instrument was upgraded by S. Gosain (NSO) and the SOLIS Team in 2015 to perform full Stokes polarimetry of the chromospheric Ca II 854.2 nm spectral line. This upgrade has provided the capability to derive vector magnetograms in the chromosphere over a large field-of-view (full disk) and on a daily basis. This is a unique capability now available with SOLIS/VSM instrumentation.

Chromospheric vector magnetograms have several potential benefits for the study of solar activity phenomena. Due to lower plasma beta, the magnetic forces dominate at this height and the magnetic field is closer to force-free approximation (i.e., Lorentz force being zero) than at the photospheric level. This makes the chromospheric vector field data very useful for coronal field extrapolations and determination of free magnetic energy in active regions. Further, the flare related changes in the magnetic configuration of solar active regions can be studied more effectively with chromospheric vector magnetograms as the field is more responsive to coronal field changes in comparison to the magnetic field in the lower layers where the field is essentially line-tied to the dense photosphere.



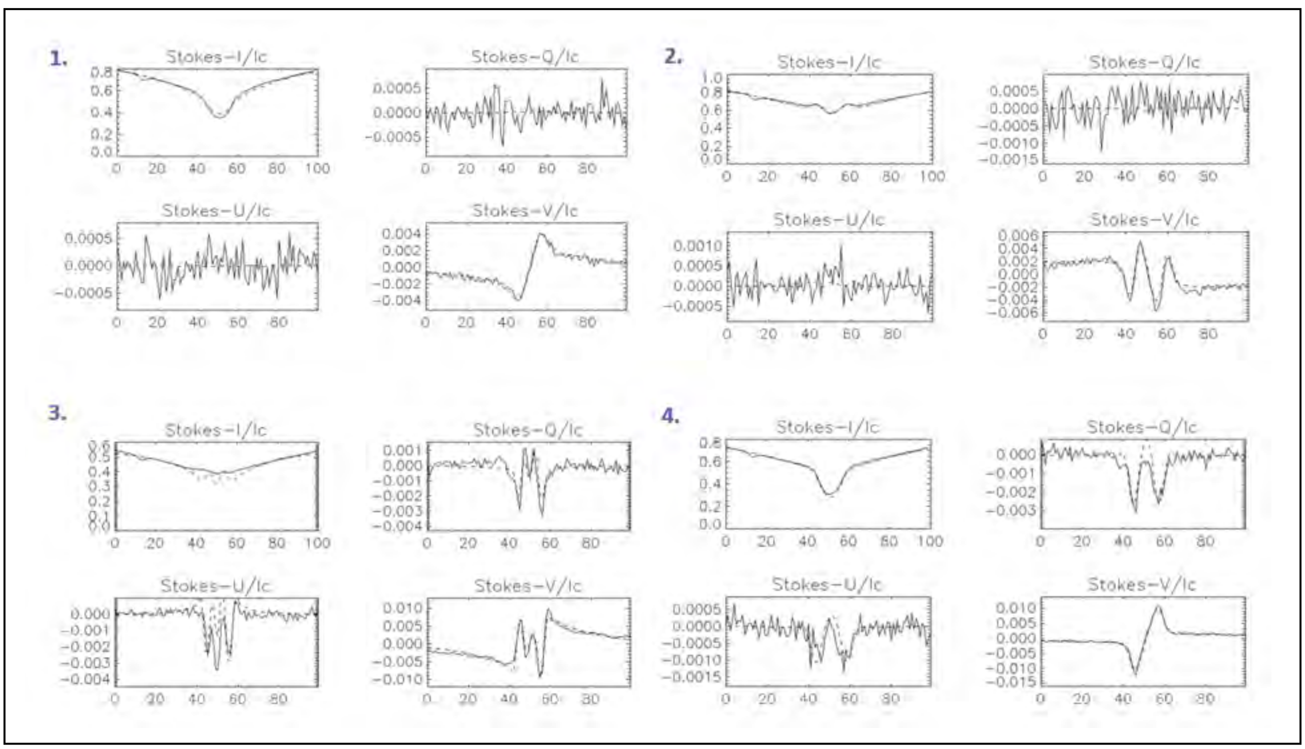


Figure 2.3-1. *Observed Stokes-I, Q, U,V profiles corresponding to the locations marked 1-4 on the Ca II line core intensity map of the sunspot are shown as a solid line in the subpanels marked 1-4. The dashed line in the plots shows the synthetic profile corresponding to the best-fit model retrieved by the non-local thermodynamic equilibrium (NLTE) inversion code NICOLE. Locations 1-4 are representative of the moat-flow region, penumbra, light-bridge and plage, respectively.*

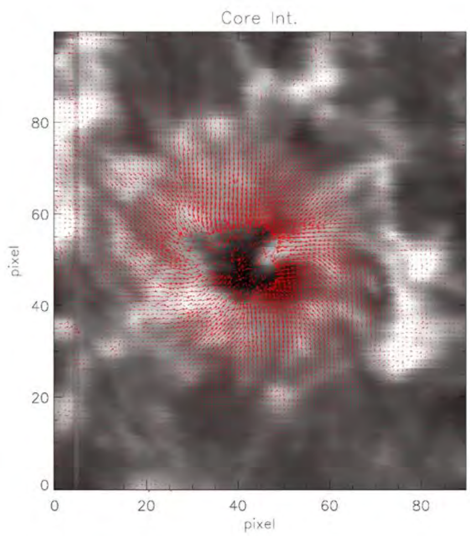


Figure 2.3-2. *The transverse magnetic field component is shown as red arrows over the line core intensity map of the sunspot. The map is derived by (i) NLTE inversion of all the pixels in the map; and (ii) disambiguation of the field azimuth by choosing the direction that makes acute angle with respect to the potential field azimuth. The longest arrow corresponds to ~2800 G.*

However, the retrieval of magnetic field vector in the chromosphere is not easy. Strong chromospheric lines such as Ca II 854.2 nm form under non-local thermodynamic equilibrium (NLTE) conditions and hence require more detailed radiative transfer computations. NLTE inversions of the SOLIS/VSM spectra using the NICOLE code (Socas-Navarro et al., *ApJ*, **507**, 1998) were carried out in an active region, where the signal-to-noise ratio is better than quiet Sun. The model fits with observations from different representative locations in and around the sunspot and is shown in Figure 2.3-1. The fits are remarkably good in most locations. A full map of the field vector derived from these NLTE inversions is shown in Figure 2.3-2. Further improvements are being made in stray-light determination. This work has been presented by S. Gosain and colleagues at the 2016 AAS Solar Physics Division meeting and is being prepared for journal publication.

2.4 Horizontal Flows in Active Regions from Ring-Diagram and Local Correlation Tracking Methods

Continuous high-cadence and high spatial resolution Dopplergrams allow the study of subsurface dynamics that may be further extended to explore precursors of visible solar activity on the surface. Since the p-mode power is absorbed in the regions of high magnetic field, the inferences in these regions are often presumed to have large uncertainties. Using the Dopplergrams from space-borne Helioseismic Magnetic Imager (HMI), K. Jain (NSO) et al. (*ApJ* **816** (5), 2016) compare horizontal flows in a shear layer below the surface and the photospheric layer in and around active regions. The photospheric flows are calculated using the local correlation tracking (LCT) method, while the ring-diagram technique of helioseismology is used to infer flows in the subphotospheric shear layer. Jain and colleagues find a strong positive correlation between flows from both methods near the surface. This implies that despite the absorption of acoustic power in the regions of strong magnetic field, the flows inferred from the helioseismology are comparable to those from the surface measurements. The magnitudes, however, are significantly different; the flows from the LCT method are smaller by a factor of two than the helioseismic measurements. Also, the median difference between the direction of corresponding vectors is 49°.

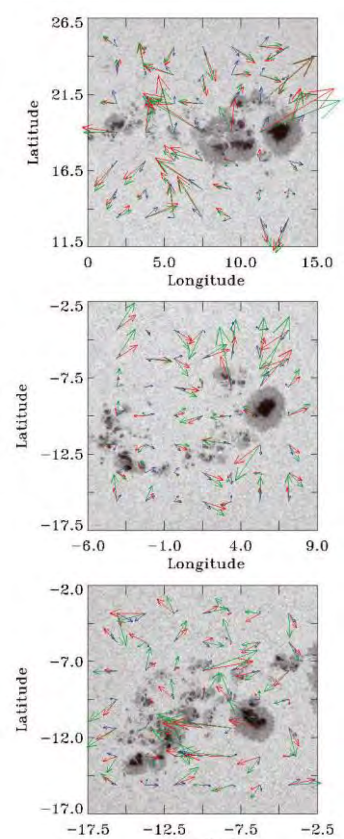


Figure 2.4. *Comparison of horizontal flows – photospheric from LCT (blue), sub-photospheric from f-modes (green) and sub-photospheric inverted velocities (red) in AR 11339 (top), AR 11890 (middle), and AR 11944 (bottom).*

2.5 Spectral and Imaging Observations of a White-light Solar Flare in the Mid-infrared

Matt Penn (NSO) et al. (*ApJ* **819**, L30, 2016) conducted high-resolution observations at mid-infrared wavelengths of a minor solar flare, SOL2014-09-24T17:50 (C7.0), using Quantum Well Infrared Photodetector (QWIP) cameras at an auxiliary of the McMath-Pierce Solar Telescope. The flare emissions, the first simultaneous observations in two mid-infrared bands at 5.2 and 8.2 μm with white-light and hard X-ray coverage, revealed impulsive time variability with increases on timescales of ~4 s followed by exponential decay at ~10 s in two bright regions separated by about 13″. The brightest source is compact, unresolved spatially at the diffraction limit (1.″72 at 5.2 μm). Penn and colleagues identify the IR sources as flare ribbons also seen in white-light emission at 6173 Å observed by SDO/HMI, with twin hard X-ray sources observed by the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI), and with EUV sources (e.g., 94 Å) observed by SDO/AIA. The two infrared points have nearly the same flux density (f_ν, W m^{-2} Hz) and extrapolate to a level of about an order of magnitude below that observed in the visible band by HMI, but with a flux of more than two orders of magnitude above the free–free continuum from the hot (~15 MK) coronal flare loop observed in the X-ray range. The observations suggest that the IR emission is optically thin; this constraint and others suggest major contributions from a density less than about 4×10^{13} cm^{-3}. This emission mechanism is tentatively interpreted as predominantly free–free emission in a highly ionized but cool and rather dense chromospheric region.

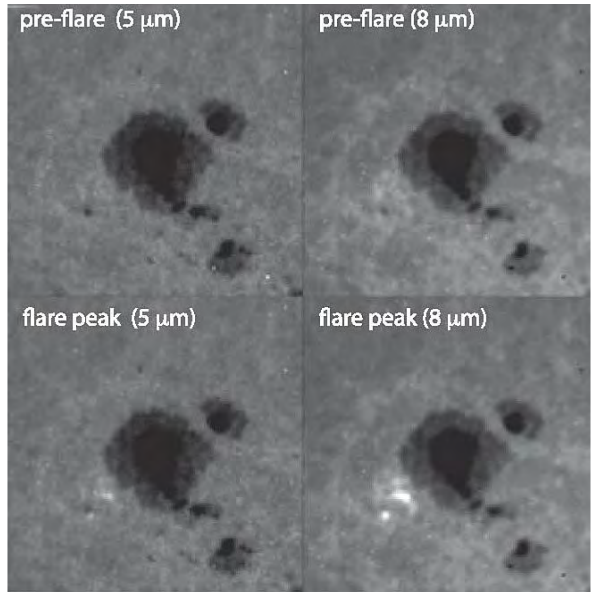


Figure 2.5-1. *Snapshot raw images: pre-flare (top), flare peak: (17:49:20 UT; bottom), with 5 μm (left) and 8 μm (right).*

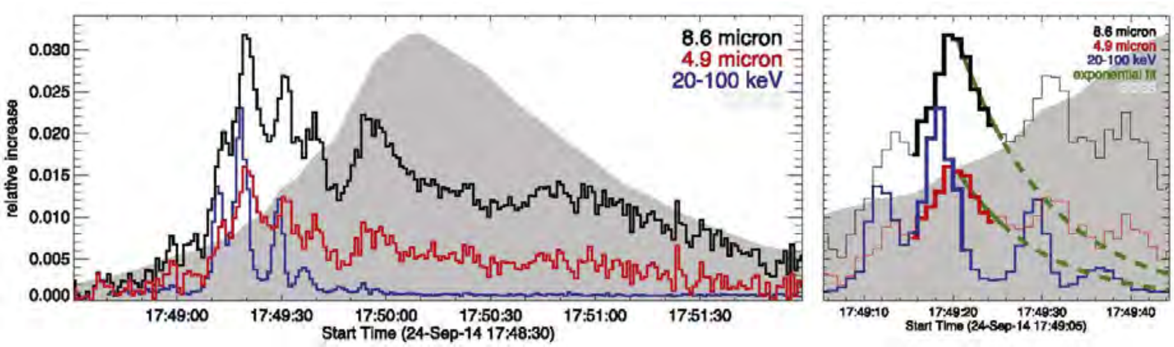


Figure 2.5-2. *Normalized time series (ΔS/S) for the compact southern sources of each wavelength, plus arbitrarily normalized time series from RHESSI hard X-rays (blue) and from the GOES 1-8 Å band (gray shaded). The RHESSI data have been demodulated to get higher time resolutions than the spin period of ~4 s (e.g., Qiu et al. 2012).*

3 SCIENTIFIC AND KEY MANAGEMENT STAFF

The NSO staff provide 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 allow 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.
Mark S. Giampapa	NSO/Tucson Site Lead; stellar dynamos and magnetic activity; asteroseismology; astrobiology.
Sanjay Gosain	Spectropolarimetry; solar magnetic fields; instrumentation.
David M. Harrington	Instrumentation; spectropolarimetry, adaptive optics, novel optical systems, detector systems, applied research, community workforce development.
John W. Harvey	NISP; solar magnetic and velocity fields; helioseismology; instrumentation.
Frank Hill	NSO Associate Director for NISP; solar oscillations; data management.
Sarah A. Jaeggli	Sunspot evolution; instrument development; astronomical polarimetry.
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.
Joseph P. McMullin	DKIST Deputy Director/Project Manager; Senior Scientist.
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.
Thomas Schad	Infrared solar spectroscopy, precision spectropolarimetry, high-resolution spectral imaging, chromospheric dynamics, coronal structure, non-equilibrium polarization physics, active region dynamics, solar activity cycles, student engagement and community outreach.
Alexandra Tritschler	DKIST operations development; solar fine structure; magnetism; Stokes polarimetry.
Han Uitenbroek	DST Program Scientist; atmospheric structure and dynamics; radiative transfer 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.
Scott Bulau	NISP Engineering & Technical Manager.
Jennifer Ditsler	NSO Director's Office Administrator.
Craig Gullixson	DST Technical and Project Manager.
Rex G. Hunter	NSO budget management; DKIST business support; Support Facilities and Business Manager.
Andrew R. Marble	NISP Data Center Manager.
Priscilla Piano	Administrative Manager: Director's office and Tucson site support; NSO grants management.

Postdoctoral Fellows

Dirk Schmidt	DKIST Postdoctoral Fellow; adaptive optics, high spatio-temporal resolution observation techniques; MCAO systems development.

Thesis Students

Courtney Peck	University of Colorado	Solar irradiance variation.
Xu Yang	New Jersey Institute of Technology	Infrared spectroscopy.

Grant-Supported Scientific Staff

Olga Burtseva	Time-distance analysis; global helioseismology; leakage matrix.
Kiran Jain	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	NISP Interior Program Scientist; helioseismology; solar activity.

Table 3.1 NSO Scientific Staff Estimated Percent FTE by Activity (FY 2016)

Name	Adm/Mgt[1]	Research[2]	EPO[3]	Project Support	User Support	Internal Comm.	External Comm.	TOTAL
Beck, C.		31.3	3.0	39.2	24.8	1.7		100.0
Bertello, L.		51.0		29.0	20.0			100.0
**Burtseva, O.		100.0						100.0
Criscuoli, S.		68.3	4.6	16.7	9.4		1.0	100.0
Giampapa, M.S.	1.0	87.7	4.5	0.0		0.5	6.3	100.0
*Gosain, S.		31.8		60.2	8.0			100.0
Harrington, D.			4.0	96.0				100.0
Harvey, J.W.		5.0		33.0	12.0			50.0
Hill, F.	80.4	2.0		12.9		3.2	1.5	100.0
Jaeggli, S.		20.0		80.0				100.0
*Jain, K.	10.0	31.2		58.3		0.5		100.0
**Kholikov, S.S.		33.0		10.0	7.0			50.0
*Komm, R.W.		95.0		5.0				100.0
Leibacher, J.W.		10.0		73.1		9.0	7.9	100.0
Marino, J.	22.0	10.0		68.0				100.0
Martinez Pillet, V.	98.0		2.0					100.0
Penn, M.J.		34.4	19.3	36.3	10.0			100.0
*Petrie, G.J.D.		62.0	8.0	30.0				100.0
Pevtsov, A.A.	5.2	70.5	3.2	15.5		0.5	5.1	100.0
Reardon, K.P.		25.0		55.8	19.2			100.0
Rimmele, T.R.	75.8	1.0	1.0	20.2			2.0	100.0
Schad, T.A		48.0	8.0	44.0				100.0
Schmidt, D.		10.0		90.0				100.0
*Tripathy, S.C.		72.0	0.0	27.0		1.0		100.0
Tritschler, A.	15.1	3.2	4.0	92.8				100.0
Uitenbroek, H.		18.7	0.5	36.3	33.2	6.6	4.7	100.0
Woeger, F.	98.0		2.0					100.0

*Partially grant supported
**Fully grant supported

[1]Administrative and/or Management Tasks.
[2]Research, including participation in scientific conferences.
[3]Educational 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 Kiepenheuer Institute built the Gregor telescope 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 diffraction-limited solar telescope with strong user demand and excellent scientific output. The DST has five Exit ports, one of which feeds a well-established AO system that is well matched to seeing conditions. This port accommodates a variety of diffraction-limited, facility-class instrumentation, including the Spectro-Polarimeter for Infrared and Optical Regions (SPINOR), the Interferometric BIdimensional Spectrometer (IBIS), the Facility Infrared Spectrograph (FIRS), and the Rapid Oscillations of the Solar Atmosphere (ROSA). This suite of instruments and matched AO system have made the DST one of the most powerful facilities available in terms of post-focus instrumentation.

In addition to supporting the solar community, 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 Spectropolarimeter) of DKIST. SPINOR is a precursor to DKIST's ViSP (Visible Spectropolarimeter) 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 have been 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 were 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 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.

4.1.1.2 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 Spectropolarimeter (ViSP) that is being developed by HAO for the DKIST

4.1.1.3 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 through FY 2017. 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.

4.1.1.4 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 pipelines have been created for the most used facility instruments, IBIS, FIRS, and SPINOR, and are available through the NSO website (*http://nsosp.nso.edu/dst-pipelines*). These software packages are supported by the NSO science 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 high-resolution, diffraction-limited imaging at the DST, with a goal of testing models of magneto-convection 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 have now been extensively evaluated.

4.1.5 Divestiture Planning

The National Solar Observatory is fully committed to operating the Dunn Solar Telescope and its full complement of instruments through FY 2017. However, the transition of personnel and resources to operations of the DKIST on Haleakalā has already started, and this has implications for operations at current facilities such as the DST. A reduced staff of two operators and a technical staff of three personnel will provide observational support in 2016. As a result, the telescope will be operated five days a week, avoiding mostly weekends and holidays. Users have been asked to account for these reduced operations in their observing time requests. In addition, there will be limited on-site science support available, which will be allocated as needed. NSO continues to provide support for data reduction pipelines, which are available on the website (*nsosp.nso.edu/dst-pipelines*). The NSO/Sac Peak TAC will continue to allocate observing time at the DST on a quarterly basis, with the usual deadlines for each quarter one and a half months before the start of the quarter.

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 telescope, including perhaps providing continued access to NSO for both testing and educational purposes. Recently, NMSU has established a plan that includes efforts to turn the DST into a training facility for the younger generations of astronomers and engineers and to continue to use the telescope for science-grade observations. NMSU has discussed this plan with the NSF. The NSF has endorsed a two-year bridge period until a full consortium comes to fruition. This period overlaps with NSO's presence at Sac Peak during FY 2017.

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 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 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 The Northrop Grumman Starshade Experiment

A Northrop Grumman group of engineers and astronomers have demonstrated the ability of a petal shaped starshade to clearly see low-intensity celestial objects during several series of engineering tests at the McMath-Pierce Solar Telescope on Kitt Peak. This was the first time a starshade was tested against actual astronomical objects. The starshade is a sunflower-shaped coronagraph disc designed to block starlight that interferes with telescopic observations of dimmed objects. The "petals" of the "sunflower" shape of the starshade are intended to eliminate the direct light from the central star. A 10-centimeter (four-inch) starshade positioned in front of the 2.1-meter (39-inch) heliostat mirror was tested against Jupiter, Saturn and other celestial objects. The 2.1-meter heliostat mirror at the McMath-

Pierce is conducive for starshade research as it provides distance between the starshade and the imaging telescope while tracking stars and planets to the accuracies required for long exposure times.

In spite of the successes achieved in the different campaigns, it is unclear at present whether these capabilities provide a future path for sustained operations of the McMath after FY 2017.

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, FY 2015 and FY 2016. To accommodate for the ramp down in NSF support, a group of interested users have donated funds.

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.

For FY 2017, NSO has informed NOAO that we will discontinue using the motor pool service, thus reducing the McMath Joint Use Fee for Kitt Peak to $48K, about half of the FY 2016 amount. Additional details about the transition plans for the McMath are provided in Section 8.2

4.3 Access to NSO Data

4.3.1 Digital Library

In addition to its dedicated telescopes, the NSO operates a Digital Library that provides synoptic data sets 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 (FTS) interferograms and transformed spectra, the Sacramento Peak Evans Solar Facility (ESF) spectroheliograms and coronal scans, and solar activity indices. In addition, NISP archives comprise GONG and SOLIS instrument data sets. 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 the US Air Force 557th Weather Wing (previously known as AFWA), AFRL, NOAA/SWPC, and NorthWest Research Associates (NWRA) for space weather prediction applications. The SOLIS data archive includes the VSM, ISS and FDP. In 2016, about 40 TB of combined NISP and Digital Library data were exported to over 1,300 users. Additional data from the Improved Solar Observing Optical Network (ISOON) is being added. We also host 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 DST Service Mode observing runs.

Since the inception of the Digital Library in May 1998, more than 390 TB of science data files have been distributed to the user community. 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 has 800 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 2.0 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. 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., for 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 either NSO or the NSF; it is fully supported by NASA. For further information, see *http://vso.nso.edu/*. The VSO maintains a number of remote mirror nodes for the data set produced by NASA's SDO mission with one of these nodes located at NSO. SDO downloads via the VSO are currently close to a 1 TB/day.

The VSO is developing a spatial search capability . 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 plans to 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.

NSO will continue to be a central component of the VSO for the foreseeable future.

5 DKIST CONSTRUCTION AND OPERATIONS RAMP UP

5.1 Introduction

Figure 5.1-1 *DKIST Team at the January 2016 all-hands meeting.*

On 15 December 2013, the 4-meter Advanced Technology Solar Telescope was renamed the Daniel K. Inouye Solar Telescope (DKIST). The re-naming 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 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 2011 NSF sponsored *Community Workshop on the Future of Ground-based Solar Physics* 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://dkist.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 5.2-1).

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 require-ments 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 (DC) 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 website, *http://dkist.nso.edu*. The most important capabilities of the DKIST are summarized in Table 5.2-1.

Table 5.2-1. 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
λ = 4 μ	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	5×10^{-4}
Wavelength Coverage	300 nm to 28 micron
Facility-Class, First-Light Instruments	

Figure 5.2-1. *Site progress as seen in December 2015 (left) and progress in November 2016 (right).*

In FY 2016, at the facility site at Haleakalā Observatories (HO), the DKIST completed significant progress on the observatory facilities. The assembly of both the Support and Operations (S&O) building and the Enclosure were completed. Internal to the building, fit and finish activities are ongoing with room-by-room drywall, painting and paneling activities; electrical conduits, boxes and connections are being completed throughout. The pFlow lift (primary mechanism for the Telescope Mount Assembly (TMA) and later optical installation and removal for coating activities) was commissioned. The enclosure jib and bridge cranes were installed. Ventilation gates and controls along with flashing and seals were completed, culminating in meeting the water-tight milestone in

August 2016. Electrical controls were also installed and commissioned and the start of maintenance activities has begun. Facility thermal systems advanced with the completion of enclosure/lower enclosure duct work, compressed air installation along with flexible manufacturing system (FMS) control cabinets, air handlers, fan coils and heat exchangers as well as Utility Building variable frequency drive (VFD) primary loop circulation.

The Telescope Mount Assembly installation, broken into the Coudé Rotator and Telescope Mount Base components, began in December 2015 and is expected to be completed at the end of 2017. Figure 5.2-2 shows the incremental progress throughout the year. In particular, the prior assembly and testing at the Ingersoll facility in Rockford, Illinois, has enabled an accelerated assembly and alignment process with the Coudé Rotator bearing alignment flatness meeting (the 50 micron!) specification over the 9.6-m diameter as well as meeting specification for the alignment of the azimuth axis between the Coudé rotator and mount base and fitting of the Coudé encoder tape.

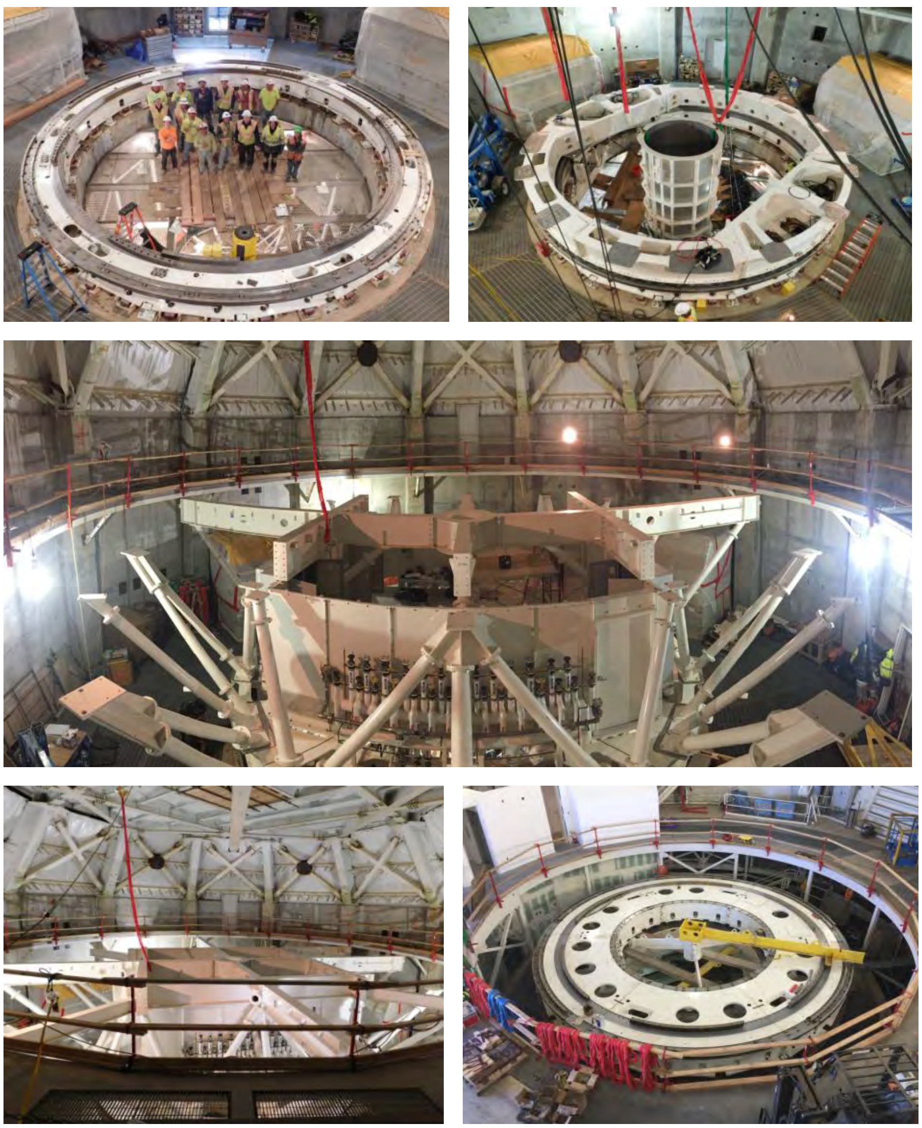


Figure 5.2-2. *TMA Development. (Left, Top) January 2016: The rough align and grouting was completed for the Coudé Rotator Bearing base. (Right, Top) May 2016: Installation of the Coudé saddles onto the Azimuth Bearing was completed. (Middle) August 2016: Coudé Rotator support structure assembly in place; (Lower, Left) Primary steel structure assembly was completed on the Coudé Rotator platform. (Lower, Right): Telescope Mount Base installation and alignment at the Telescope level of the facility.*

Off-site, the instrument development projects continued with transitions from design to fabrication for the Visible Spectropolarimeter (ViSP) and Diffraction-Limited Near-Infrared Spectropolarimeter (DL-NIRSP). Fabrication of the Cryo-NIRSP (Cryogenic Near-IR Spectropolarimeter) continued, including the delivery of the spectrograph (following successful interim inspections) as well as optical components. The Visible Broadband Imager (VBI) continued its integration process, making strides in completing interfaces with facility systems, development of the speckle reconstruction pipeline, and testing of optical systems. The United Kingdom (UK) Consortium camera development made strong progress, delivering the engineering camera to the project for interface testing and integration to the software controls; they are on track to deliver the instrument systems on time.

Figure 5.2-3. *Ongoing testing of the upgraded spectropolarimeter, which is now capable of testing into the near-infrared (1650 nm). This shows the installed, aligned and running setup for data collection from 380-1650 nm (September 2016, Boulder Lab).*

The High-Level Software team completed enhancements to the prototype Data Handling System (DHS) delivered it to instrument partners for testing; in addition, an assembled camera line (one fifth of the full system in operations) was installed in Tucson for testing and has demonstrated meeting specifications for high-speed, high-volume data flow and export. In addition, the Telescope Control System (TCS) was added to the Quality Assurance testing framework, adding nightly regression runs to demonstrate the needed robustness for operations. A hardware/software integration unit was assembled to allow simulation of the observatory facility for remote testing and development; an additional unit was assembled in Boulder for testing science experiment support and interfaces for science and operators. The M1 mirror remained in storage throughout this year, while the M1 Cell Assembly continued its thermal factory acceptance testing (FAT); issues were identified which took several months to resolve, but the acceptance is expected for January 2017. The Feed Optics assemblies and mirrors were completed and Feed Optics Control Software (FOCS) testing is ongoing in Tucson, Arizona. Wavefront Correction (WFC) assembled a clean room integration lab in Boulder for integration testing of the subsystems along with the real-time controls. Polarization Analysis & Calibration (PA&C) developed a laboratory spectropolarimeter to enable earlier testing and characterization of optical components to ensure meeting polarization specifications. The team also successfully planned and executed their Preliminary Design Review (PDR) phase triggering some early procurements to ensure meeting schedule in the out-years.

Figure 5.2-4. *Installation of the optical benches into the WFC clean room (Boulder Lab) was completed (February 2016).*

5.2.1 Schedule Status

A subsystem view of intermediate milestone highlights is shown in Table 5.2-2. 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, Testing 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 5.2-2. DKIST Future Major System Milestones

Support Facilities	2017-Apr 2018-Apr	Coating and Cleaning Facilities Available on Site Site Closeout (apron, water tanks, drainage, parking, etc.)
Optical Systems	2017-Feb 2018-Dec 2019-Jan	M1 Cell Assembly Acceptance Complete M1 Integration (install, align, LUT development) Optical Chain (M1-M9) First Light Ready
Telescope Mount Assembly	2017-Apr 2018-Jan	Coudé Acceptance Testing Complete TMA Mount Installation Complete
Facility Thermal Systems	2017-Sep 2018-Nov 2019-Mar	Telescope Mount Thermal System Complete Enclosure Thermal System Complete Facility Thermal Systems Complete
Wavefront Correction	2018-Apr 2018-Oct	WFC System Testing Complete (Boulder Lab) WFC Coudé Installation Complete
Software	2017-Apr 2017-Jun 2017-Jul	Camera Software Final Release Data Handling System Processing Quality Assurance Pipeline Observatory Control Software Final Release
Instruments	2018-Feb 2019-Mar 2019-Jun 2019-Sep	VBI on Site (Partner instruments received May 2018-March 2019) VBI Integration Complete VBI First Light Demonstration Start of Science Operations

5.2.2 Financial Status

Following the Project Re-baseline, the Total Project Cost was established as $344.1M. To date, the project has received $288M; $146M from the American Recovery and Reinvestment Act of 2009 (ARRA) and $142M from the Major Research Equipment and Facilities Construction (MREFC). The ARRA funding was provided in January 2010 and expired at the end of FY 2015. The MREFC funding is provided annually, based on supporting the planned spending and commitments through 2019.

5.3 DKIST Operations Ramp-Up Phase: Overview

The main deliverables of the ramp-up phase include the DKIST Data Center (DC), which will handle processing, archiving, and distribution to the community of DKIST data products. At first light the DKIST Data Center will deliver calibrated data for all first light instruments.

It should be noted that operations planning and ramp up to operations, including the implementation of a Data Center and a Remote Office Building (ROB), are the responsibility of the NSO but are outside the scope of the DKIST construction project.

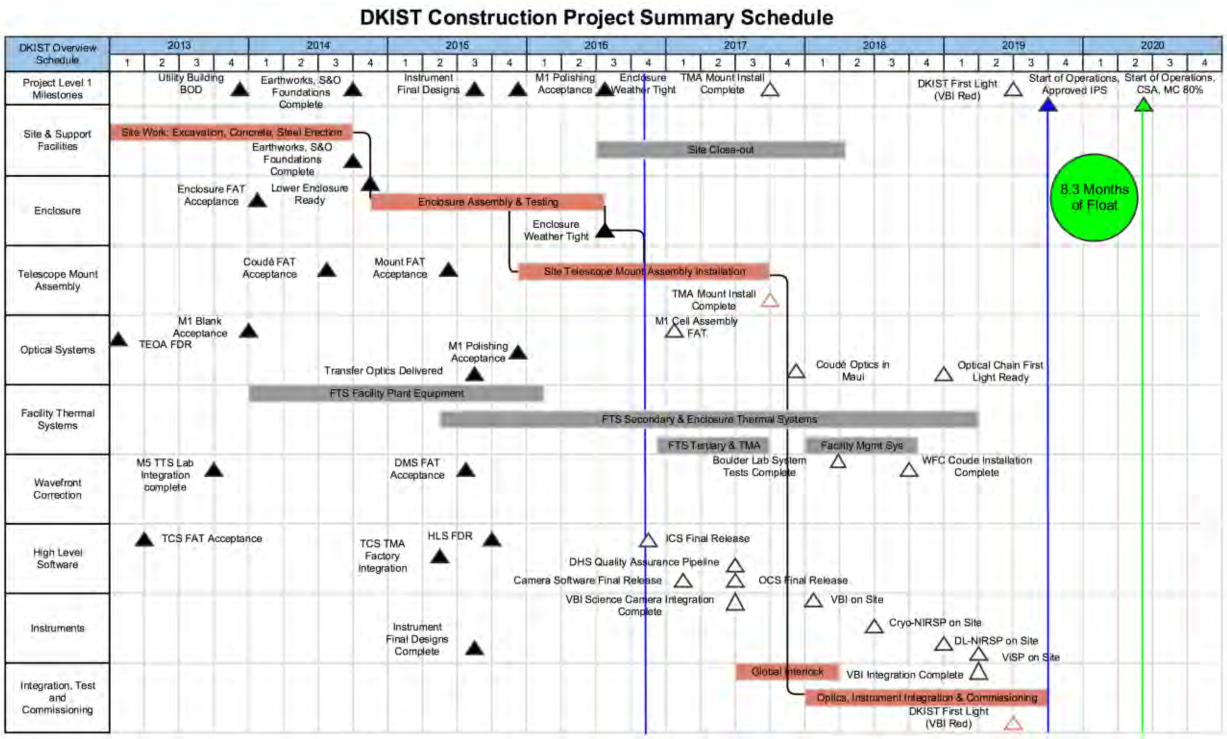


Figure 5.2-5. *DKIST summary view of intermediate milestones; critical path activities are marked in red.*

In FY 2016, operations planning, development of operations processes, support tools and implementtation of infrastructure necessary for DKIST operations continued. The ramp up of science and technical staff will continue until full operations staffing is reached at the beginning of operations, currently projected for September of 2019.

The Data Center concluded documentation of formal high-level science requirements and operational concepts definition, and work continues on detailed derived systems requirements, conceptual designs and prototyping of key technologies. The Data Center team has worked towards its Conceptual Design Review, which is scheduled for early 2017.

The development of the Critical Science Plan (CSP) continued in FY16. The Chair of the Science Working Group is leading the effort supported by NSO staff. A community CSP workshop was held in conjunction with the Solar Physics Division meeting in Boulder. Significant progress was made with engaging a broad section of the community in the development of detailed observing scenarios and experiments. The goal is to ensure science readiness of the community.

During FY 2016, the design for the ROB was finalized, an Environmental Assessment was performed and the bid process for construction was initiated. We note that the schedule for ROB construction has slipped significantly while funding and NSF and AURA worked out approval processes. As a consequence of the delayed construction of the ROB, the cost for construction has increased due to market pressures on Maui. In addition, there is currently no office space available for operations staff on Maui. The leased space that houses the construction staff is already oversubscribed. The three Maui-based DKIST science staff are currently housed at the Institute for Astronomy (IfA) Advanced

Technology Research Center (ATRC), where they work closely with the instrument partners at IfA. Ramp up of Maui-based staff has been slower than planned for this reason.

Ramp up of operations staff continued during FY16. Two experienced operators were hired and began training at the Dunn Solar Telescope, where telescope systems and prototype instruments similar to the DKIST instruments are operated for users. In addition, the new observers and the DST chief observer have begun a training program in Boulder that exposes them to the actual DKIST systems, including VBI and adaptive optics, and allows them to gain experience with the Boulder-based end-to-end simulator. Operators are expected to participate in users' acceptance testing and will be involved in the integration and commissioning phase at DKIST. DKIST currently has three science staff located on Maui.

The staffing plan for the full-up 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 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. Two science positions on Maui have been filled. 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. As the operations planning progresses, these initial staffing plans will be refined. We expect that a significant number of construction project staff will transition to operations; thus we are taking measures to encourage and facilitate such a transition in order to retain and maintain the expert knowledge that exists within the DKIST construction staff into the operations phase.

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 DKIST Science Working Group has begun discussions on science goals and high-level concepts for second-generation instrumentation.

5.3.1 Data Center Development

5.3.1.1 Overview

The DKIST Data Center will provide computational resources supporting DKIST science goals and broadening community engagement, data use, and inquiry in solar physics. The DC will be the primary long-term repository of DKIST scientific and ancillary data, and will produce calibrated data sets while maintaining association to its measurement and engineering context. 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.

5.3.1.2 FY 2016 Accomplishments

During FY 2016, development efforts on Data Center continued apace, with the delivery and review of operational concept definition and scientific requirements documents, the elaboration of traceable engineering requirements, and the conceptual design of major and supporting system elements. A months-long, iterative scientific requirements definition effort led by the DKIST DC Project Manager concluded in the third quarter (3Q), with the delivery of approved science requirements. A conceptual design meeting stringent budgetary constraints and satisfying known requirements was developed and will be reviewed in FY17. Significant progress was made on interface control documents between the Data Center and the DKIST construction project. An extensible prototype "hybrid cloud" computing platform was designed and delivered, supporting ongoing development activity to be sustained until the start of DKIST operations. Ongoing definition and analysis of instrument and facility calibrations was refined and extended, leveraging current and past exemplar instruments in service at the DST and elsewhere, and leading to intensive collaborative engagement with DKIST instrument partners to deliver calibration plans. Programmatically, initial sizing estimates for necessary hardware and software development labor were delivered, as well as a stable incoming data rate estimate drawn from realistic profiles of facility usage.

<u>FY 2016 Milestones Summary</u>

- *Complete Data Center Operational Concepts Definition.*
  - Milestone completed 3Q FY16. Delivery late due to lengthy science requirements definition and review period.
- *Complete Baseline Data Center Science Requirements.*
  - Milestone completed 3Q FY16. Delivery late due to lengthy science requirements definition and review period.
- *Complete Project Execution and Management Plans.*
  - 70% complete. Will be completed 100% for Conceptual Design Review (2Q FY17).
- *Complete Approved Baseline Data Center System Design Requirements.*
  - 80% complete. Will be completed 100% prior to Conceptual Design Review (2Q FY17).
- *Complete Approved Baseline Data Center Subsystem Design Requirements.*
  - 30% complete. Will be completed 100% prior to Preliminary Design Review (4Q FY17).
- *Successfully conclude Data Center Conceptual Design Review.*
  - CoDR is scheduled for 2Q FY17. 4Q arrival of FY15 funding and lengthy science requirements definition and review period has led to corresponding delay of DC development.
- *Successfully conclude Data Center Preliminary Design Review.*
  - Preliminary Design Review shifted to 4Q FY17. 4Q arrival of FY15 funding and lengthy science requirements definition and review period has led to corresponding delay of DC development.
- *Successfully conclude Data Center Final Design Review.*
  - Final Design Review shifted to FY18 due to delays in conceptual and preliminary design development.

5.3.1.3 FY 2017 Plan

During FY 2017, the development of the Data Center will focus on delivery of system and subsystem engineering requirements, conceptual and preliminary design.

During the first quarter (1Q), Data Center staff will complete a months-long effort to produce conceptual architecture and system-level engineering requirements that are traceable, derived from, and complement the approved scientific requirements and operational concepts definition delivered during FY16. The conceptual architecture includes the following major functional components: the daily transfer of DKIST data from Maui to Boulder; the capability to annually store and curate 3.2 PB of annually-produced data and metadata; the detailed instrumental and polarimetric calibration of this data; the ability for users to freely and openly search available calibrated data, and request these for download.

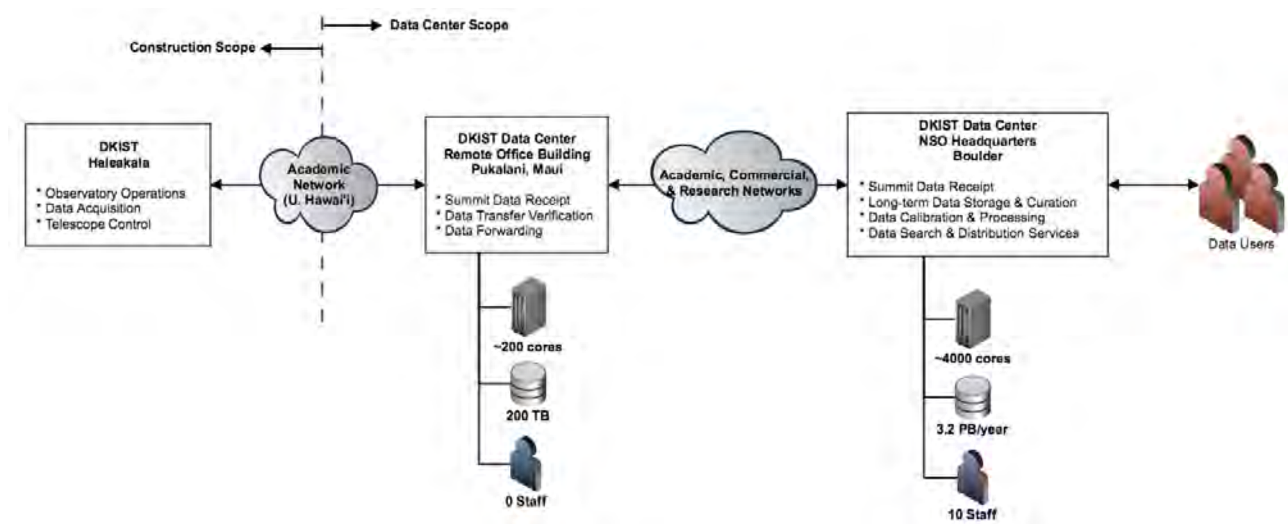


Figure 5.3-2. *High-level Data Center data flow.*

The set of system requirements contains how the architecture is to be satisfied by functional and performance capabilities that the Data Center development effort must deliver at DKIST first light, and beyond. These requirements specify

- how and how fast data would be transferred from the telescope to Boulder (fault-tolerant, checkpointed, and recoverably performed within ten days of acquisition on the summit);
- the use of a science-driven, budget-informed data retention mechanism, wherein a committee composed of scientific and technical advisors determines what data can be compressed, downsampled, or deleted;
- the numerous types of information that must be ingested and persisted by Data Center systems, from observational metadata to parameters and values necessary to perform calibrations;
- how and which calibrations to perform, and what quality metrics are associated with output data;

- how a user will search data and metadata, by specifying values for parameters characterizing instruments and observations, such as instrument and mode used, temporal, spatial, spectral and polarimetric constraints, and quality; and
- how users will be capable of checkpointed, restartable download of data customized from their query results.

The architecture and requirements are balanced against known stringent budgetary constraints to optimize use of available resources and time. Achieving this balance is met through the use of detailed use and cost estimation tools for Data Center resources, whether hardware components like hard drives, software development costs, or network and storage bandwidth estimation drawn from detailed performance models utilizing industrial engineering principles. These tools provide a timely comparison of known system-level scope against available budget, and are key artifacts duly supporting the conceptual design and review process.

The requirements development and conceptual architecture efforts will be supported by limited proof-of-concept prototyping to support whether chosen architecture components are technically feasible, are cost-effective, and can be customized for Data Center use by first light. This prototyping effort has been underway, and will continue in 1Q FY17 and beyond. Examples of ongoing work include

- Use of the Globus Toolkit for data transfer from the summit to Boulder, and for distribution to end-users;
- Integration of popular, well-supported open-source system monitoring and provision tools, such as Saltstack, Openstack, and Elasticsearch/Logstash/Kibana/Grafana;
- Adoption of high-performance computing workflow systems, including HTCondor/Pegasus, PanDA, and SLURM;
- Definition and iteration on prototype calibration codes written in Python, partly utilizing existing and past instruments as a starting point to distill substantial experience and knowledge of calibrating realistic, ground-based solar data with application to DKIST instruments and polarimetry;
- Mockups and prototypes of search and data distribution interfaces and process.

During 2Q, the Data Center staff will be finalizing the preparation for and completing the successful Data Center Conceptual Design Review. Following incorporation of feedback from the review, for the rest of FY17 the staff will continue requirements definition and review, focusing now on refining system requirements to subsystem engineering requirements, while simultaneously working through their resource impacts with the cost and usage estimation tools being developed. Through several iterative and focused sprints, the staff will refine the conceptual design into a formal preliminary design. This will include a significant prototyping effort, to identify where known technologies can meet required specifications, where customization is needed, or where new approaches need to be formulated and integrated. Additionally, the Data Center, in collaboration with internal staff and instrument partners, will begin development of DKIST-specific calibration code prototypes, drawing on algorithm documentation delivered during 2Q-3Q. Finally, an extensive formal project management documentation is due for delivery at the Preliminary Design Review, containing for example approaches and strategies for project execution, risk management, cost estimation, change control, requirements management and satisfaction, and change and configuration control.

FY 2017 Milestones

- *Complete Data Center System Requirements (1Q FY17).*
- *Successfully conclude Data Center Conceptual Design Review (2Q FY17).*
- *Complete Data Center Subsystem Requirements (3Q FY17).*
- *Successfully conclude Data Center Preliminary Design Review (4Q FY17).*

5.3.2 Operational Tools

5.3.2.1 Overview

The Operational Tools are software written to support the submission and management of scientific proposals to use the DKIST, create observational programs, and aggregate operational information. The Operational Tools function in concert with the DKIST High-Level Software to execute observations and with the Data Center to ensure that adequate metadata are provided to end users.

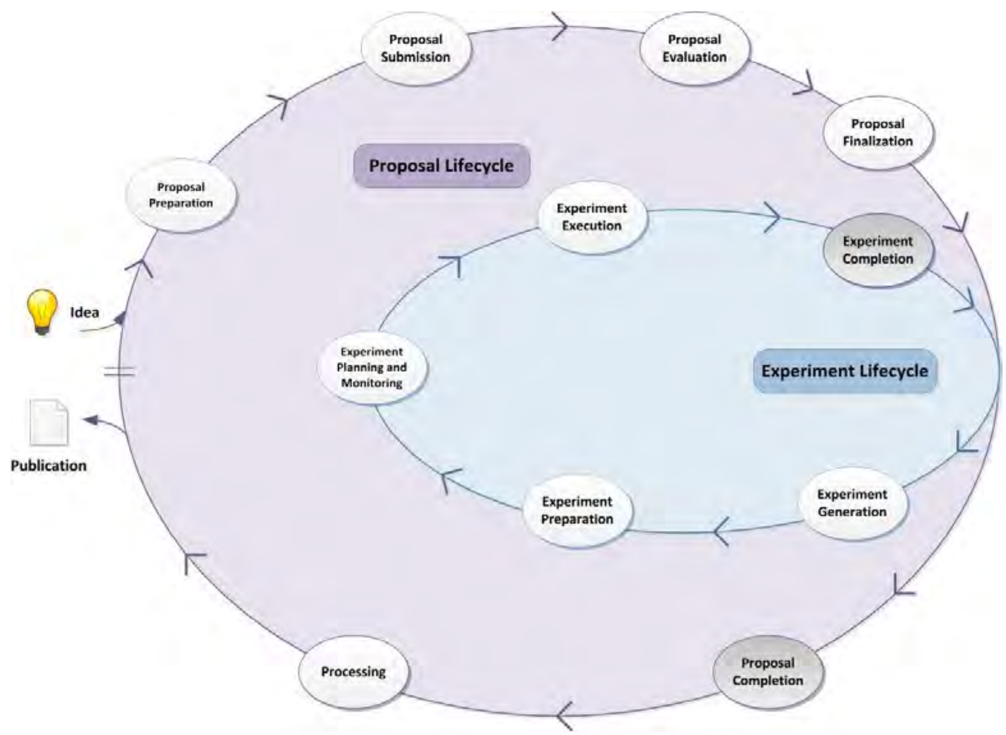


Figure 5.3-2. *Proposal and Experiment lifecycles. The operations software tools support users and operations staff performing the listed functions.*

5.3.2.2 FY 2016 Accomplishments

During FY 2016, development focused on the delivery and review of operational concepts definition, scientific requirements, and conceptual design. An intensive, collaborative-needs analysis was performed to identify, clarify, and narrow scope for the Operational Tools, resulting in a refined operational concepts definition, draft science requirements, and initial conceptual design.

FY 2016 Milestones Summary

- *Complete Operational Tools Operational Concept Definition (OCD) and Use Cases.*
    - 90% complete. Final review to be complete in 1Q FY17.
- *Complete Operational Tools High-Level Requirements and Traceability.*
    - 40% complete, to be complete 2Q FY17. Lengthy operational concepts definition, staff outages, and staff matrixing to Data Center resulted in delay.
- *Successfully conduct requirements review.*
    - 25% complete. Science requirements review scheduled for 2Q FY17. Q4 arrival of FY15 funding, and availability of key staff matrixed to Data Center development, has led to corresponding delay of Operations tools development.
- *Successfully Conduct Preliminary Design Review.*
    - Design Requirements 10% complete. Engineering design requirements review scheduled for 3Q FY17. PDR scheduled for 4Q FY17. Q4 arrival of FY15 funding, and availability of key staff matrixed to Data Center development, has led to corresponding delay of Operations tools development.

5.3.2.3 FY 2017 Plan

During FY 2017, the development of the Operational Tools will focus on delivery of science and system design requirements, and their review and approval. Initially, high-level science requirements for each toolset will be developed, reviewed, and delivered, followed by engineering requirements that specify performance and functional requirements needed to support the user and scientific needs. Both of these efforts will continue prototyping efforts, particularly with regard to user interface functionality improvement and data flow design, and will identify technologies appropriate to identified need. In 4Q a Preliminary Design Review will review the traceability of the preliminary design to scientific and engineering requirements as well as feasibility given known technologies.

FY 2017 Milestones

- *Complete Operational Tools Science Requirements (2Q FY17).*
- *Complete Operational Tools Design Requirements (3Q FY17).*
- *Complete Operational Tools Preliminary Design Review (4Q FY17).*

5.3.3 Maui Remote Office Building

The Remote Office Building (ROB) on Maui will serve as the local 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 infra-structure. The function of this ROB will be similar to Gemini's Base Facility in Hilo, Hawai'i, by providing a facility from which the science, operations and maintenance activities of the Maui-based DKIST staff 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 work space, the ROB will support specialized functions including: hosting a remote operations room where staff and visiting scientists can participate in and guide summit operations; limited initial data processing and preparation for data transfer to the NSO Data Center in Boulder; and providing a small instrument laboratory for maintenance and future upgrades to DKIST instrumentation.

Figure 5.3-3. *Rendering of the DKIST Remote Office Building on Maui.*

Once constructed, the ROB will serve as the off-summit center for day-to-day operations of the DKIST. We note that remote operations functions from the ROB will initially be limited to real-time monitoring of instrument performance and health, data quality assessment and resident astronomers providing guidance to the summit operations staff. The ROB will provide individual and shared office spaces. On average, 25 to 30 permanent and visiting staff would use the facility daily. Limited instrument/optics lab and workshop space is provided. In addition to staff and visitor vehicles, it is anticipated that several facility vehicles for the DKIST facility would be staged in the parking lot of the ROB.

Detailed analyses of several options, including different construction and lease options, show that construction of the ROB on a property in Pukalani is by far the most cost effective option for the life of DKIST operations. This property is adjacent to the University of Hawaiʻi Institute for Astronomy (UH/IfA) building. In addition to direct cost savings, 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.

AURA purchased the land in FY 2015, but construction of the ROB continued to be delayed during FY16 while funding and approval processes were worked out by the NSF. In FY16, NSF authorized AURA to conduct the Environmental Assessment (EA) process. NSF was involved throughout the EA process, which was successfully concluded in spring of 2016. With NSF approval, the multi-month county permitting process was started. No issues or delays are expected. AURA was authorized by the NSF to start the formal Request for Proposal (RFP) process after NSF reviewed the RFP documents prepared by the project. An Announcement of Opportunity for ROB-002, Remote Office Building Construction RFP, was made publicly available on 30 June 2016. A pre-bid meeting and site walkthrough was held on 27 July. Five bidders provided proposals by the 07 September due date. The Source Selection Evaluation Board (SSEB) issued their recommendation to award the construction contract in October 2016. Pending approval by the AURA Board and NSF, and successful contract negotiations with the selected firm, construction is expected to begin in December 2016.

5.4 DKIST Science Working Group

Community participation in and support of the DKIST effort occurs through the DKIST Science Working Group (SWG) as well as the Data Center and Operations Sub-Working Groups. The SWG is currently chaired by Mark Rast of the University of Colorado, Boulder, and members include non-project scientists, project co-investigators, and instrument PIs (Table 5.4-1).

TABLE 5.4-1. DKIST SCIENCE WORKING GROUP

Count	Last Name	First Name	Affiliation	Country	Status	Start 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	U. Colorado	US	Member	2014	2 years
5	DeForest	Craig	SWRI	US	Member	2002	2 years
6	Deng	Yuanyong	NAOC	China	Member	2013	2 years
7	dePontieu	Bart	Lockheed	US	Member	2015	2 years
8	Fletcher	Lyndsay	U. Glasgow	UK	Member	2002	2 years
9	Hurlburt	Neal	LMSAL	US	Member	2011	2 years
10	Judge	Phil	HAO	US	Member	2003	2 years
20	Haugen	Stein Vidar	ITA	Norway	Member	2014	2 years
12	Martens	Piet	MSU	US	Member	2014	2 years
13	Parnell	Clare	St. Andrews	UK	Member	2011	2 years
14	Qiu	Jiong	MSU	US	Member	2011	2 years
15	Rast	Mark	U. Colorado	US	Member	2013	2 years
16	Rempel	Mattias	HAO	US	Member	2015	2 years
17	Rubio	Luis Bellot	IAA	Spain	Member	2002	2 years
18	Scullion	Eamon	TCD	Ireland	Member	2014	2 years
19	Socas-Navarro	Hector	IAC	Spain	Member	2002	2 years
21	Goode	Phil	NJIT	US	Co-I		
22	Knoelker	Michael	HAO	US	Co-I		
23	Rosner	Robert	U. Chicago	US	Co-I		
24	Kuhn	Jeff	IFA	US	Co-I & Instrument PI		
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		

With construction well underway and instrument capabilities well defined, the focus of the SWG has shifted largely to the development of the Critical Science Plans (CSP) and through it use expectations that influence operations planning, data handling and processing requirements, data products and data dissemination. Broad community involvement in the CSP is being facilitated via websites, http://dkist.nso.edu/CSP, which describe the science objectives and instrument capabilities and includes links to abstracts of all Science Use Cases currently under development, and https://nso-atst.atlassian.net/, which is a collaborative environment for Science Use Case development. The latter is password protected. These Science Use Cases will be consolidated and converted to community member PI-led observing proposals that will be executed as the CSP during the first one to two years of operations.

Current CSP topics and community leaders include but are not limited to:

Magnetohydrodynamics and Dynamo Processes

- Small-Scale Photospheric Magnetic Fields: Formation, Structure, Dynamics
- Turbulent Dynamo: Hanle-Effect Imaging of the Quiet-Sun
- Wave Generation and Propagation
- Magnetoconvective Modulation of Solar Luminosity
- Sunspots: Umbral and Penumbral Structure and Dynamics
- Flux Emergence and Active Region Formation

Flares and Eruptive Activity

- Flare Precursors in the Lower Atmosphere
- Magnetic Field Connectivity Changes in Flares
- Flare Electron Diagnostics in Visible Light
- Flare Footpoints at their Fundamental Scales
- Coronal Mass Ejections

Magnetic Connectivity, Mass and Energy Flows in the Solar Atmosphere

- The Chromosphere-Corona Connection
- Spicule Physics
- Formation, Evolution and Eruption of Non-Potential Configuration
- Multilayer Magnetometry and Atmospheric Heating
- Coronal Waves and Energy Fluxes
- Energy and Magnetic Helicity in Coronal Structures
- Prominence Morphology, Connectivity, and Lifecycles
- Infra-Red Survey of the Solar Atmosphere

Long-Term Studies of the Sun

- Evolution of Surface Magnetism
- Polar Fields in Time
- Small-Scale Field Contributions to Irradiance

Special Topics and Broader Implications

- Magnetic Reconnection in Weakly Ionized Plasmas
- Turbulence in a Radiative Boundary Layer
- Sun-Grazing Comets

The SWG annual meeting was held on 11–13 October 2016 in Las Cruces, NM. The agenda included:

- Project, Instrument, and Data Center Updates;
- Discussion of scientific impact of potential VTF delays;

- Description and demonstration of Instrument Perfomance Calculators;
- Discussion of strategies for target-of-opportunity observations and interfaace with Coudé configuration;
- Definition of proposed upcoming Crititcal Science Plan workshop goals and format;
- Discussion of web interface and strategies for enhanced community participation in the CSP;
- Science Use Case development.

The meeting was very productive in refining Instrument Performance Calculator capability expectations, arriving at a suitable collaborative web-based environment, and clarifying obstacles to community participation. Most of the CSP Science Use Cases make use of the DKIST capability to combine several instruments for simultaneous observations. The Beam Splitter Configuration and Data Rate Examination tools were assessed to be particularly useful in understanding the capabilities and limitations of the instrument suite.

Additional activities over the year, in collaboration with DKIST project and instrument scientists, include development of concise instrument, Facility Instrument Distribution Optics, and Data Handling System summaries for community use during Science Use Case development, a special DKIST Science session at the Solar Physics Division meeting, the first DKIST CSP Science Use Case Development Workshop, a one-day workshop with over 50 participants and resulted in 20 Science Use Case initiations, and successful coordination of proposals to the NSF Astronomy and Astrophysics Research Grants (AAG) that resulted in about 15 independent PI-led proposals to advance science in preparation for DKIST.

During FY 2017, the SWG will continue to refine and further detail CSP Science Use Cases, and focus on engaging a broader section of the community in Science Use Case development through a series of workshops.

What follows is the proposed schedule to develop detailed observing proposals with strong community involvement:

November 2016	Call for DKIST CSP Science Use Case Development Workshop proposals
February 2017	Workshop proposal selection
Fall 2017	Annual SWG meeting
2017 – 2018	Community led DKIST CSP Science Use Case Development Workshops

5.5 Instrumentation Development

In FY 2017, we plan to arrive at formal requirements definition, perform a conceptual design study, and lead a preliminary design contract, most likely with a university partner. In response to the significant cost increase for the construction of the ROB that was indicated by the cost estimate based on the 100% completed design documentation and later confirmed by the bid process second generation instrumentation development, limb AO upgrade and DKIST MCAO were pursued less aggressively than planned in FY 2016.

Conceptual design for a thermal infrared imager, which in terms of solar observations is a largely unexplored spectral region, has started in FY16 and is in progress. The effort is led by NSO Astronomer Matt Penn, who is collaborating closely with scientists at NASA.

Penn continues work in collaboration with the New Jersey Institute of Technology (NJIT) which has led to science observations with the Cryogenic Infrared Spectrograph (CYRA) instrument at Big Bear Solar Observatory (BBSO). The CYRA instrument is a cooled-grating slit spectrograph with a detector that is sensitive from about 1000 nm to 5000 nm. Scientific goals for the CYRA instrument include photospheric magnetic studies at 4135 nm, temperature minimum investigations using the CO lines at 2333 nm and 4666 nm, chromospheric observations with H I lines, and perhaps coronal studies using the 3934 nm line.

After initial tests of CYRA (Figure 5.5-1) revealed that the cooling system of the instrument was shaking the images in the dewar, modifications were made including installing new coiled rope copper thermal straps from the cold heads to the optical surfaces inside CYRA. After installing these straps, the measured image vibrations are small and within the specifications of the instrument. CYRA is an analog for the Cryo-NIRSP instrument at DKIST, and shares several design characteristics. Lessons learned with CYRA provide valuable input to CRYO-NIRSP. For example, the thermal straps in Cryo-NIRSP are the same copper rope elements as the ones now in CYRA (Figure 5.5-2), and we expect minimal vibration transfer in Cryo-NIRSP as well. Scientific use of CYRA is proceeding with NJIT PhD student Yang Xu's dissertation work; his Ti I and CO observations are expected to lead directly to more scientific investigation at DKIST using Cryo-NIRSP after the instrument is commissioned.

Figure 5.5-1. *Early tests of the CYRA instrument at BBSO with Tom Ayres (CU-Boulder), Matt Penn (NSO), and the NJIT/BBSO staff.*

Figure 5.5-2. *Closeup of the thermal straps used in the DKIST instrument Cryo-NIRSP during a visit to Universal Cryogenics in Tucson. These are the same thermal straps tested in the BBSO/CYRA instrument which successfully reduced the vibration noise transferred from the dewar cooling systems.*

NSO/DKIST continued to develop national and international partnerships. The DKIST construction successfully forged collaboration with the United Kingdom. A UK consortium led by Queen's University, Belfast will deliver visible cameras for DKIST first-light instruments. The development of camera sensors is progressing at Andor Technology in Belfast. In FY16, a formal agreement between AURA and the UK was signed. A design review was conducted at Andor in Belfast and Andor began fabrication of the detector. First devices are undergoing testing.

A strong partnership continues 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). 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 New Solar Telescope (NST) at Big Bear Solar Observatory serve as pathfinder telescopes for the development, implementation and science demonstration of MCAO. NSO, NJIT and KIS AO teams are collaborating closely.

In FY16, several on-sky engineering runs with MCAO were performed at the NST at BBSO. NSO scientists Jose Marino and Dirk Schmidt are leading a significant part of the development effort. The complex system, comprising three deformable mirrors, was successfully locked on solar granulation and for the first time demonstrated, visibly in real time, its ability to significantly extend the corrected field of view. This marks a major break-through for solar MCAO development. Figure 5.5-3 shows the direct comparison between MCAO (left), Conventional AO (CAO, right) and Ground-Layer AO (GLAO, middle)).

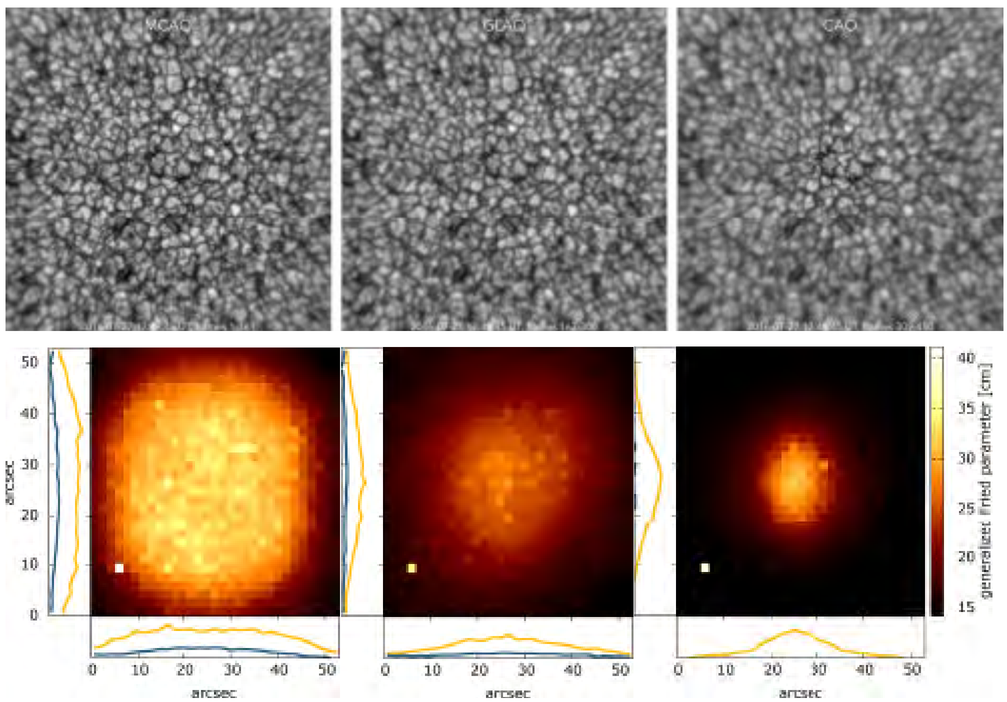


Figure 5.5-3. *The Sun observed in a field of view of 53 arcsec x 53 arcsec with MCAO, GLAO, and CAO correction with Clear on the NST through a filter for the titanium oxide line (705.7 ± 5 nm). The bottom row shows in color code a quantitative measure for the degree of correction (bright orange indicates good correction).*

A publication summarizing the system design and recent results was submitted to a referred journal. The MCAO collaboration is laying the ground-work for implementation of MCAO at DKIST. Based on the BBSO experience, it is now understood what system configurations work and which don't. System optimization as well as improving robustness is work that will continue in FY17.

In addition to the on-sky MCAO experiments at BBSO, the NSO team is developing a comprehensive simulator that can provide end-to-end performance simulation of MCAO systems, including the NST and envisioned DKIST MCAO. The system is using high performance parallel processing hardware located at NSO in Boulder. The simulator will provide invaluable guidance for performance optimization of the NST system and design of the DKIST MCAO.

In FY 2017, NSO/DKIST will continue the collaboration, with the goal of fully demonstrating and quantifying the MCAO utility and performance at BBSO and GREGOR. A joint proposal to NSF for supporting this work was prepared by the partners. For FY17, we plan to begin a conceptual design phase for DKIST MCAO.

The DKIST Science Working Group has requested that adaptive optics capability for off-limb structures such as solar prominences be provided. Erupting prominences (or filaments when observed on disk) are at the source of coronal mass ejections. Prominence AO will greatly enhance our ability to measure physical parameters in prominences, such as the magnetic field, with sufficient precision and sensitivity. The prominence prototype system was developed by a graduate student from NMSU and demonstrated feasibility of the concept. Our plans to further develop the prominence AO prototype at the Dunn Solar Telescope in FY16 had to be postponed. In FY17, we plan to involve students and a postdoc in advancing the prototype performance characterization and optimization. Concepts for an upgrade to the DKIST AO system that will provide the community with prominence AO capability will flow from this effort. Conceptual design work for a DKIST prominence AO wavefront sensor is also planned for FY17. The upgrade is envisioned to be implemented within the first two years of operations.

5.6 DKIST Critical Science Plan Workshops

The DKIST Critical Science Plan (CSP) defines the science experiments that the facility must accomplish shortly after the commissioning phase to demonstrate its success. These experiments and observations aim to produce high-impact refereed papers that will showcase DKIST discoveries. The CSP includes all critical cases whereby the DKIST, with its first generation of instruments, is expected to reveal scientific breakthroughs. Naturally, these cases will focus on ultrahigh spatial resolution, coronagraphic, and multi-wavelength (UV cutoff 5-micron) capabilities. The CSP is a "living" document that's available online and evolves in response to discoveries made in both modeling and observational programs (see http://dkist.nso.edu/CSP). The CSP includes specific Science Use Cases developed by the community and ideally should contain all of the information needed to prepare an observing proposal. Each Science Use Case has a PI identified online. To help produce these Science Use Cases, NSO is planning to conduct a series of workshops for the broader community to interact with NSO scientists and the DKIST first-light instrument partners. This activity will start in FY 2017 and extend to FY 2018. In an effort to engage the US community, we are planning to host the majority of the CSP sorkshops at US universities.

After a discussion with the DKIST SWG, NSO announced an opportunity to nominate five Research Area Team Leaders to run Critical Science Plan Workshops. Each Team Leader will be responsible for a single one-off workshop or a two-workshop series (depending on needs) in one of five Research Areas:

1) Magnetohydrodynamics and Dynamo Processes.
2) Flares and Eruptive Activity.
3) Magnetic Connectivity, Mass and Energy Flow in the Solar atmosphere.
4) Long-Term Studies of the Sun.
5) Special Topics and Broader Implications.

These Research Areas mirror the current Critical Science Plan structure. The Science Use Cases produced at the CSP Workshops, after being converted into observing proposals, will provide the basis for the first PI-led science observations to be made with the DKIST. Closing the loop, NSO plans to support data processing and analysis activities during early operations to facilitate data usage by the PI-led Science Use Case. These plans will include a Visiting Program for in-residence activities of Research-Area Team Leaders and students at NSO Headquarters in Boulder. These in-residence periods will take place during execution of the Critical Science Plan, expected during 2020/21.

The workshops can be proposed in one of two organizational formats: a single one-off three-day workshop or a series of two two-day workshops. In either case, the aim is to submit upon workshop completion a set of (10 – 30 minimum) finished PI-led Science Use Cases that outline the scientific motivation, instrument suite, and observing strategies to be employed. The submitted Science Use Cases should provide a level of specificity that allows, beyond the workshops proper, ready conversion into Observing Proposals. NSO is requesting that the workshop proposals specify how the workshop format will serve to meet this goal. Research-Area Team Leaders' proposals must include the following elements:

1. The Research Area of Interest and a brief description of the scientific focus of the workshops proposed.
2. The organizational structure of the two workshops and how that will serve to meet the Science Use Case submission goal.
3. Host institutions for the workshop sites (must be US university campus locales, unless partnerships providing matching resources are identified).
4. Membership of the Science Organizing Committee and the Local Organizing Committee chair.
5. List of possible participants in the workshops (12 – 15).
6. Strawman list of possible Science Use Cases under the proposed Research Area.
7. Discussion of how to incorporate Science Use Cases already submitted to the DKIST CSP (see http://dkist.nso.edu/CSPand https://nso-atst.atlassian.net/) into the broader team effort.
8. Plan for workshop participation of students, and external resources available for student support.
9. Plan for Research Area Team Leaders and students in-residence activities at NSO Headquarters.
10. Budget needed to support travel (domestic only), accommodations, and workshop costs.
11. Special budgetary considerations or needs.

For each of the CSP Workshops NSO will commit:

1. Funding for the workshops with a maximum of $25K per Research Area. This funding is available for travel and lodging of the RA science team members and logistical aspects for the workshops.
2. Administrative support to organize the workshops.
3. A contact scientist who will channel any questions that might arise to the DKIST operations team and/or the first-light instrument partners.

6 NSO INTEGRATED SYNOPTIC PROGRAM

The NSO Integrated Synoptic Program (NISP) was formed in July 2011, combining the Global Oscillation Network Group (GONG) and Synoptic Optical Long-term Investigations of the Sun (SOLIS) programs, increasing organizational efficiency, and yielding greater scientific synergy. Together, DKIST and 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 physics 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. Space missions are also vulnerable to the effects of solar flares and CMEs, cannot be repaired, and are extremely expensive.

In addition to supporting solar variation and helioseismology studies, NISP is a valuable source of data for national space weather needs. The 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. This and an Office of Management and Budget (OMB) directive to NOAA has led to the initiation of a partnership with the Space Weather Prediction Center (SWPC) that will provide substantial operational support to NISP for at least the next five years. Space weather has become increasingly important to national security and planning. The development of improvements in forecasting space weather has been identified by the White House as a crucial activity, as shown by the October 2015 release of the National Space Weather Action Plan and the October 2016 Executive Order instructing the NSF, NASA, and other federal agencies to support space weather research. NISP is an active participant in these activities.

Beyond maintaining normal operations, advancing scientific research, and providing support to the community, NISP's activities and goals in 2016 and 2017 have been and continue to be heavily impacted by relocation efforts as well as several large special initiatives. In addition to completing the migration of its staff to Colorado, NISP is continuing the process of relocating its Data Center operations from Tucson to Boulder and preparing to move both SOLIS and the GONG engineering site. In parallel, NISP has embarked on a major refurbishment of the GONG network, is migrating its space weather data processing to NOAA/SWPC, is taking restorative measures to improve the GONG magnetic zeropoint, and is completing additional instrument upgrades. Loss of personnel resulting, in part, from NISP's relocation and budget uncertainties have made carrying out this ambitious agenda challenging; however, a dedicated and resourceful staff is committed to NISP's forward progress on each of these fronts.

6.1 GONG

GONG 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 high-sensitivity magnetograms averaged over ten minutes, seismic images of the farside of the Sun, and 20-second cadence 2K×2K Hα intensity images are also available. These data are used by the US Air Force (USAF) 557th Weather Wing and NOAA/SPWC for space weather forecasts, by the Air Force Research Laboratory (AFRL) to drive their Air Force Data Assimilative Photospheric flux Transport (ADAPT) forecast of the solar magnetic field using data assimilation, and by the NASA Community Coordinated Modeling Center (CCMC) to initiate many of its models. These magnetograms are currently the highest cadence measurements of their type available and provide data for studies of rapid changes in the Sun's magnetic field. The Hα images are an increasingly popular data product, and have been used to study filaments, flares, and the oscillations of the chromosphere.

6.1.1 GONG Refurbishment

The GONG network has been operating since 1995, and many instrumental components are aging and becoming increasingly difficult to maintain. Thus, the NSF has allocated $2.5M for NSO to refurbish GONG so that it can continue to operate for another 10 to 15 years while its replacement, SPRING (see Section 6.6), is developed. In consultation with the NSO Users' Committee and community space weather forecasters, the upgrades listed below are underway. Part of the refurbishment funds will be used to support two two-year staff positions to help carry out this work. As of the writing of this report, it is anticipated that this project will be completed in April 2018.

- Replacement 1K×1K cameras – A model has been selected, and a test unit is in-house and under evaluation.
- Improved polarization modulators – Procurement of replacement modulators with tighter tolerances is underway, with delivery of a test unit expected by the end of calendar 2016.
- Tunable Hα filters – The current filters only sample the Hα line center and will be replaced with ones that can be tuned to the red and blue wings of the line as well. This will allow for Doppler-shift velocity measurements of erupting filaments. A source for these filters has been identified, and a test unit is being prepared by the vendor.
- Data Center upgrades – Additional nodes for the data storage cluster have been purchased and incorporated. Replacement data processing servers were also acquired and are being configured.
- Refreshed workstations – Aging workstations that currently handle Hα and 676.7 nm observations separately will be replaced with more-powerful redundant instrument computers that will accommodate both.
- Additional improvements – Weather station upgrades, replacement of aging optics, increased network bandwith where needed, and resupplying of spare components are also underway.

6.1.2 GONG Magnetic Zeropoint

Recent comparisons of coronal hole maps derived from GONG data with EUV observations of the Sun revealed that instrumental biases in the zeropoint of GONG magnetograms were not being adequately corrected for. Subsequent analyses determined that this was caused both by increased spatial complexity in those biases and limitations in the zeropoint correction algorithms that were originally developed during a relatively quiet phase of solar activity. Commensurate with the importance of these zeropoint corrections to space weather applications, significant time and effort have been invested in improving them.

Non-planar spatial structure in the instrumental biases was traced back to leakage of signal into the initial few data frames acquired after modulator transitions. Installation of new polarization modulators with tighter tolerances (as part of the GONG refurbishment) and more precise tuning of those modulators will limit the number of affected frames, while modifications to the data acquisition system now allow us to exclude the first three frames. Figure 6.1-1 shows the effect of such frame-exclusion on the spatially averaged magnetic field. In this particular example, the overall instrumental magnetic bias is significantly reduced relative to the corresponding measurement from SOLIS/VSM, and there is less variation throughout the day. Implementing frame-exclusion across the network and analyzing resulting coronal hole maps is underway. Simultaneously, algorithmic improvements that allow for a more sophisticated treatment of the residual planar magnetic biases are being investigated and tested.

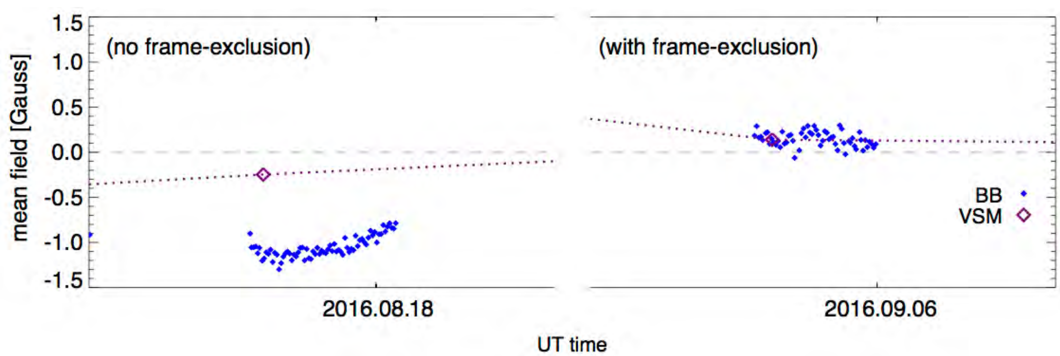


Figure 6.1-1. *The spatially averaged magnetic field (within 90% of the solar radius) throughout the day at the Big Bear (BB) site with (right) and without (left) frame-exclusion. The same value for SOLIS's daily VSM observation is included for reference.*

6.1.3 Relocation of the GONG Engineering Site

The two GONG engineering units currently in Tucson must be moved to Boulder by the end of 2017. After the initial selection of a site adjacent to the NSO Headquarters building unexpectedly fell through, the University of Colorado has provided three additional possible locations within walking distance (see Figure 6.1-2). Of these, the two eastern most locations will likely be adversely affected by planned building construction projects, but the western-most location appears to be suitable. Although near Boulder Creek, it lies outside of the 100- and 500-year floodplains and was unaffected by historic flooding in 2013. A benefit of such a nearby location is the potential for using the GONG engineering instruments for educational outreach purposes. As of the writing of this report, NISP is finalizing the site selection with the University of Colorado and the land owner.

6.2 SOLIS

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

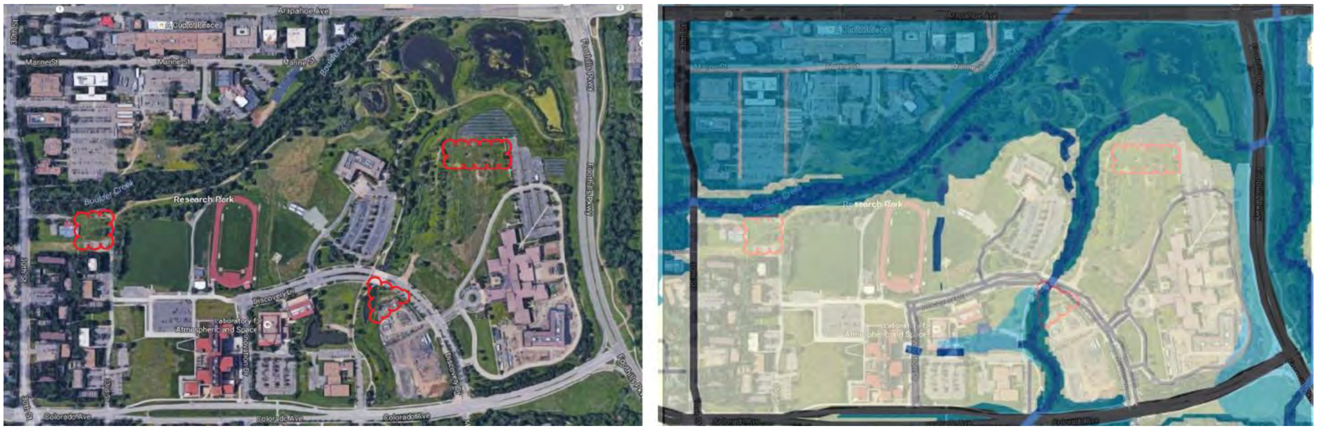


Figure 6.1-2. *Aerial map showing the three Boulder locations for the GONG engineering site (outlined in red) proposed by the University of Colorado with (right) and without (left) 100- and 500-year floodplain overlays. The NSO Headquarters building is indicated.*

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 Ca II 854.2 nm line and the Fe I 630.15/630.25 nm line pair. The FDP can take observations with a temporal cadence as short as 10 seconds in several spectral lines including Hα, 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, Hα 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.

6.2.1 SOLIS Instrument Upgrades

In late 2015, a polarization modulator that provides the full Stokes profiles in the chromospheric spectral line at 854.2 nm was installed in the VSM. This allows for nearly simultaneous photospheric and chromospheric vector magnetic field measurements, a powerful combination for understanding the structure of magnetic fields in stellar atmospheres. This new and unique capability to routinely provide synoptic full-disk chromospheric magnetograms should lead to greatly improved boundary conditions for extrapolations of the solar magnetic field into the corona. This could ultimately provide predictions of the direction of the magnetic field inside Coronal Mass Ejections (CMEs), which are needed for geomagnetic storm forecasts.

Initial processing of the 854.2 nm vector observations was modeled after that of the 630.2 nm vector data, was limited to generating spectra, and did not produce any public data products. However, in mid-2016, NISP began providing the community with tailored Quick-Look magnetic field data products and spatially registered spectral cubes for I, Q, U, and V (see Figure 6.2-1a). For the Quick-Look images (see Figure 6.2-1b), a modified center-of-gravity approach is used to estimate the field strength, while the inclination and azimuth are calculated using the approaches of Auer, Heasley & House (1977) and Ronan, Mickey & Orrall (1987), respectively. Further improvements to the Quick-Look images via an integral method are being investigated, while providing the spectra to the

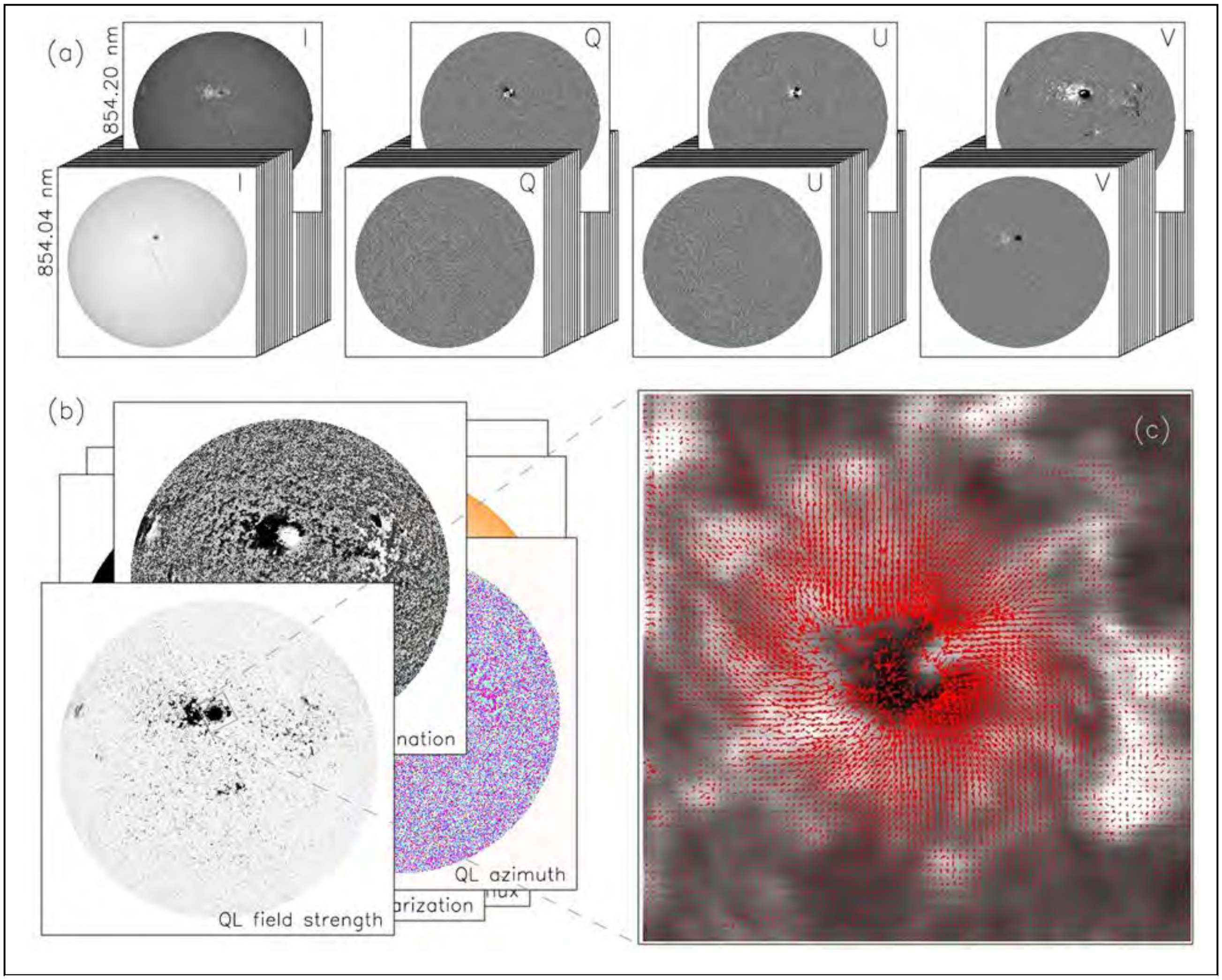


Figure 6.2-1. *Spectral cubes (a) and Quick-Look magnetic field and geometry data products (b) for VSM 854.2 nm vector observations (the examples shown here are for April 13, 2016) are made available to the community to facilitate advances such as the those shown in (c) for a single large sunspot using the NLTE inversion code NICOLE (courtesy S. Gosain and H. Socas-Navarro).*

community will hopefully facilitate advances in processing such as those shown in Figure 6.2.-1c for a single sunspot from April 13, 2016 using the NLTE inversion code NICOLE.

Another major instrumental upgrade to SOLIS will be the addition of the Visible Tunable Filter (VTF) to the FDP. The VTF was built and tested in May 2014; however, installation was delayed by the relocation of SOLIS from Kitt Peak to Tucson, repairs of resultant damage to the FDP, and the addition of the 854.2 nm vector modulator to the VSM. Current plans include installing the VTF prior to the final relocation of SOLIS.

6.2.2 Relocation of SOLIS

In August 2014, SOLIS was temporarily relocated from Kitt Peak to the University of Arizona agricultural campus in preparation for NSO's relocation to Boulder, the divestment of the McMP, and planned instrument upgrades. After consideration of several sites, it is now planned that SOLIS will be permanently relocated to Big Bear Solar Observatory (BBSO) in FY 2017. BBSO is an excellent site for the type of synoptic observations acquired by SOLIS; the daytime seeing is very good and, perhaps more importantly, it is generally stable over the course of the day. BBSO also enjoys a clear daytime fraction of 71% and has sufficient internet bandwidth to transfer SOLIS data to the NISP Data Center. BBSO is three hours east of the DKIST site, so SOLIS will be able to supply solar context observations to DKIST in advance of daily operations. As of the writing of this report, applications for building and other permits are being processed by the San Bernardino County Land Planning Department for the SOLIS site location (see Figure 6.2-2).

Figure 6.2-2. *Aerial views of Big Bear Solar Observatory, with the red teardrop symbol (left) and red X (right) showing the location for SOLIS. The location of the existing GONG site (along the causeway to the BBSO telescope) is also indicated.*

6.3 NISP Data Center

Between SOLIS and GONG (post-refurbishment), NISP acquires (depending on the observing cadence of the SOLIS/FDP) approximately 370K – 470K full-disk observations in an average month. That corresponds to 900K – 990K raw data files that are transferred from the remote sites to the NISP Data Center. Those observations are processed, for both science research and space weather applications, through various pipelines resulting in roughly 10M – 11M derived data products (including intermediate ones that are primarily for internal purposes), or 5.5 – 7.4 TB of total data per month. About 50% of those files are publicly available within a minute of the observation being acquired, another 10% within 15 minutes, and 10% more within an hour. The remaining 30% are based on one to several months of observations and are provided accordingly.

In addition to the direct observations discussed already, NISP provides the community with a wide variety of derived data products, including 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, full-disk vector magnetic field maps produced from inversions of the Stokes profiles, and time series for spectral parameters as well as global and polar mean magnetic fluxes. These data products are important for understanding the Sun, its activity cycle and related space weather, and even the impact of stellar activity on habitable planets.

The NISP Data Center continues to develop processing pipelines that integrate the five NISP instruments: GONG/Hα, GONG/Doppler + magnetograms, SOLIS/VSM, SOLIS/ISS, and SOLIS/FDP. This makes the lessons of the NISP Data Center a useful input for the DKIST Data Center. Examples of recently added data products are the chromospheric vector spectral cubes and Quick-Look images (see Figure 6.2-1), photospheric vector synoptic maps, polar magnetic field time series, and synoptic maps of Hα emission above the limb. Additionally, synoptic map error estimation developed at NISP has been applied to HMI data products and made available to the community.

6.3.1 New Data Center Hardware

The total archival GONG and SOLIS data sets amount to roughly 700 TB at the beginning of FY17. Due to technical and logistical limitations associated with preserving a growing archive of this size using traditional RAID systems, NISP researched expandable file systems and invested in a DELL EMC Isilon data storage cluster in late 2016. That system is now installed in Tucson, and the time-intensive mirroring of NISP's data archives onto it is complete. At the same time, the combination of deferred maintenance for aging hardware and the need to relocate the NISP Data Center without substantial interruption of services lead NISP to acquire replacement equipment for the rest of its Data Center operations as well. This provided an opportunity to redesign the Data Center hardware plan and remedy a variety of bottlenecks, conflicts, and vulnerabilities that had accumulated over many years. The corresponding servers and tape backup system are installed in Tucson with final configuration underway, pending the relocation of the new Data Center hardware to Boulder.

6.3.2 Relocation of the NISP Data Center

The relocation of the NISP Data Center hardware to Boulder is currently slated for February 2017. This had been previously scheduled for mid-2016, but was subject to successive delays on the part of the University of Colorado with regard to the readiness of the SPSC Data Center (in the same building as the NSO Headquarters) where the NISP Data Center hardware will be located. Since the NISP network sites are independent of the Data Center, their operation will not be impacted during this transition. Furthermore, the purchase of all new hardware for the critical service components of the NISP Data Center in Boulder will allow for redundant operations during the transition and a relatively seamless switchover without significant interruption in the availability of NISP's near-real-time data products. Once that is complete, a limited amount of hardware that is not yet end-of-life, will be migrated from Tucson to Boulder to support additional non-production services (e.g., software development and scientific research).

6.4 NISP Science

To a significant degree, NISP's scientific enterprise is intermingled with the business of acquiring and processing observations. NISP scientists use insights from their own research to monitor and improve the quality of the data and to suggest and develop new data products. Examples of such interplay include the previously discussed GONG refurbishment, GONG magnetic zeropoint improvements, inversion of the new SOLIS/VSM chromospheric vector data, photospheric vector synoptic maps, Hα limb maps, and mean polar field time series.

Research into the use of local helioseismology to detect active regions before they emerge continues, and 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 continues to track 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.

Using helioseismology ring diagrams from GONG, NSO scientists can separate the behavior of the large-scale flows and the oscillation frequencies between the northern and southern hemispheres of the Sun. These observations are being used to understand the north-south asymmetric behavior of solar activity. With time-distance techniques, GONG data have revealed that the meridional north-south flows deep inside the Sun are far more complicated than assumed for dynamo models of the solar activity cycle. Thus, NISP scientific staff are participating in a NASA Grand Challenge Project to constrain dynamo models of the solar cycle using internal flows inferred from GONG and surface magnetic field measurements from SOLIS.

6.5 Space Weather

NISP has become an important provider of solar data needed to predict space weather events, particularly to the Space Weather Prediction Center (SWPC) in Boulder. Funded by NOAA, SWPC uses GONG and SOLIS data as input to drive a predictive model of terrestrial geomagnetic storms. SWPC, recognizing the value of the data and the need for its availability, declared GONG data essential for national security during the 2013 Government shutdown episode. Because of presentations at the Office of the Federal Coordinator for Meteorology (OFCM), NOAA was directed by the OMB to operationalize GONG space weather data and provide financial support for the operation of GONG. A support agreement between NOAA and the NSF is now in place, with NOAA providing $1M annually for five years to SWPC for GONG operations. NISP is working with SWPC to migrate GONG's space weather data processing pipelines into SWPC's more robust infrastructural environment and is using $820K to support operation of the GONG sites. NISP data are also used to drive models hosted by NASA's Community Coordinated Modeling Center (CCMC), and all NASA solar space missions use NISP data for context and supporting observations. A proposal to NASA's 2014 opportunity for Heliophysics Infrastructure and Data Environment Enhancements (HIDEE) was successfully funded for three years, indicating that NASA also recognizes the importance of NISP data products. In support of one component of that proposal, SOLIS area-scans of active regions being observed by NASA's Interface Region Imaging Spectrograph (IRIS) have been acquired regularly in order to provide complementary magnetic field information. However, this grant is in the final year of funding, and NASA has not announced a similar new opportunity.

Using helioseismology, NISP produces estimates of the magnetic field on the farside of the Sun that is turned away from the Earth. These provide a signal that new active regions have emerged that will appear on the Earth-facing side up to two weeks in advance, as demonstrated 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 the STEREO spacecraft move into positions where it is impossible to acquire the data. NSO is participating, along with NWRA, the Jet Propulsion Lab (JPL), and Stanford, in a NOAA-funded project to improve the reliability and understanding of farside imaging so that the technique can be used operationally. Research at the US Air Force Research Laboratory 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. NISP magnetograms are the primary source of the data that drives the AFRL data assimilation system known as ADAPT, which will be used by NOAA/SWPC for geomagnetic storm. The public release of ADAPT occurred in early 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.

6.6 Towards a Multi-Purpose Global Network

Synoptic data are 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 have led the solar physics research community to call for a new, improved synoptic 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 recommended 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 USAF, 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 progress significantly with the availability of continuous long-term multi-wavelength observations. Simultaneous helioseismic and magnetic observations would also improve understanding of acoustic wave propagation in the presence of magnetic fields, thus bringing us closer to forecasting the sub-photospheric 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 such observations in the long run is through a ground-based network similar to GONG. The ESA/NASA Solar Orbiter mission (to be launched in 2018) 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-of-sight will bring new insights about fundamental ingredients of the dynamo problem. Similarly, the combination of magnetic field observations from different perspectives, such as would be provided by the L5 Carrington mission proposed in the United Kingdom, allow for disentangling of complex projection effects that occur when observing crucial locations on the Sun such as the solar poles or the eastern limb. For example, SOLIS-like synoptic vector observations and similar Solar Orbiter 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 the USAF 557th Weather Wing and NOAA/SWPC need reliable and continuous sources of solar data. They are already using NISP facilities as a source of surface magnetic fields, Hα intensity, and helioseismic farside 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 several workshops that have been held in Boulder and in Europe to discuss and gather input on science requirements, capabilities, and instrumentation. About 100 scientists and engineers have attended the meetings or expressed interest, representing space weather agencies, solar physics research institutes, observatories, government agencies, and international organizations. The presentations of the latest workshop, held in Boulder in May 2016, can be found at http://www.science-media.org/conferencePage.php?cid=spring2016.

The instrumentation in a new network should not be a single device providing all observations, but should rather 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.

NSO, with HAO and the Kiepenheuer Institut für Sonnenphysik (KIS) in Germany, is developing the concept, and KIS has obtained funding through March 2017 from the SOLARNET program to develop the Scientific Requirements Document (delivered in May 2016) and to carry out an evaluation of instrumental concepts being done by Sanjay Gosain (NSO). NSO, along with KIS and other partner institutions, will develop a full proposal for a new network in the next two to four years. Additional US agency partners are likely to be the USAF 557th Weather Wing, NOAA/SWPC, and NASA. In addition, the Atmospheric and Geospace Sciences Division (AGS) of the NSF Geosciences Directorate supports space weather research, which necessarily uses solar synoptic data as inputs for models.

KIS has held three workshops so far to discuss the project with partners. The websites for these meetings are at:

http://www3.kis.uni-freiburg.de/~mroth/spring.html
http://www.astro.sk/SOLARNET_2ND_WORKSHOP/solarnet/first_announcement
http://www.astropa.unipa.it/Solarnet2015/Solarnet2015.html

An approximate timeline of the network effort is:

- 2016 – 2018 Work with KIS, HAO and other partners to develop concept.
- 2016 – 2018 Advocacy for agency, international, and research partnerships.
- 2017 Submit instrument development proposal to the NSF.
- 2018 Submit infrastructure development proposal to European opportunities.
- 2018 – 2019 Assuming success, begin development of infrastructure and first-light instrument.
- 2017 – 2020 Continuing advocacy with AFWA, NOAA, NASA, NSF/AGS, etc.
- 2020 Submit proposal for network infrastructure plus first-light instrument.
- 2024 Initial deployment.
- 2024 – 2029 Operations and additional instrumentation development.

7 EDUCATION AND PUBLIC OUTREACH AND BROADENING PARTICIPATION

7.1 An Enhanced Education and Public Outreach (EPO) Program

In preparation for the total solar eclipse of 2017, and with the imminent arrival of DKIST, the NSO has significantly increased efforts in education, public outreach and broadening participation through the establishment of the Office of Education and Outreach (OEO), headed by Dr. Claire Raftery. A second EPO position, to be based in Maui and focused on DKIST, is in the process of being filled, with an offer made to a candidate in December 2016.

Through the OEO, NSO's education and outreach mission has been refined as the following:

> *The Office of Education and Outreach (OEO) at the National Solar Observatory (NSO) strives to forward the Science, Technology, Engineering, and Math (STEM) initiatives of the Federal Government, by making solar science, space weather, and astronomy accessible to all. We strive to help people connect to NSO's mission to advance our knowledge of the Sun as an astronomical body and an influence on Earth.*
>
> *The OEO provides opportunities for life-long learners, students, teachers, and the general public to understand and engage with the cutting edge innovations and research conducted by NSO and its partners.*
>
> *The Office of Education and Outreach develops and implements strategic educational opportunities, designed to engage a variety of audiences, including but not limited to formal educators, informal educators, the general public, and the scientific community, as well as funding agencies and other stakeholders. Given the location of NSO's Daniel K. Inouye Solar Telescope (DKIST), particular care is paid to residents of Maui, Hawaiʻi. Providing opportunities for Hawaiian youth to engage and consider careers that would leverage the DKIST is a priority for the OEO.*

The OEO plans to achieve this mission through the following goals:

1. Inspire and engage the public and other non-expert audiences using the work developed by NSO and its partner organizations. This will be achieved through the development and implementation of stimulating and conscientious education and outreach programs.
2. Promote the use of NSO data and facilities amongst the science community and (where appropriate), the general public.
3. Communicate NSO's academic and scientific excellence across multiple platforms, including online, in person, and through the written word.
4. Engage and educate the next generation of scientists so they are prepared and enthusiastic to use NSO's data.
5. Foster an environment of inclusivity to promote and encourage involvement by anyone in the scientific process at the National Solar Observatory.

An Education and Outreach implementation plan has been drafted. Once the EPO position in Maui is filled, the plan will be finalized and made public.

7.2 The 2017 Solar Eclipse

NSO's OEO is actively preparing for the solar eclipse in a multitude of ways, from public outreach, citizen science, and formal education.

7.2.1 Citizen CATE Experiment

The goal of the Citizen Continental America Telescopic Eclipse (CATE) Experiment is to make a continuous 90-minute movie of the solar corona during the 2017 total solar eclipse by placing 60 identical telescopes along the path of totality, with overlapping fields of view. The sequence will have roughly 1-second cadence, with 2-arcsecond pixels (or smaller) covering a field-of-view of about 4000 × 4000 arcseconds, and the pointing will be centered on the center of the Sun.

A test run of the CATE experiment was conducted during the 2016 total eclipse across Indonesia. During that event, undergraduate and high school students were dispatched across the area of totality with support teams and test equipment. These teams successfully observed the eclipse, and spent the summer of 2016 reducing the data. Many essential lessons were learned, and plans for the 2017 eclipse were refined.

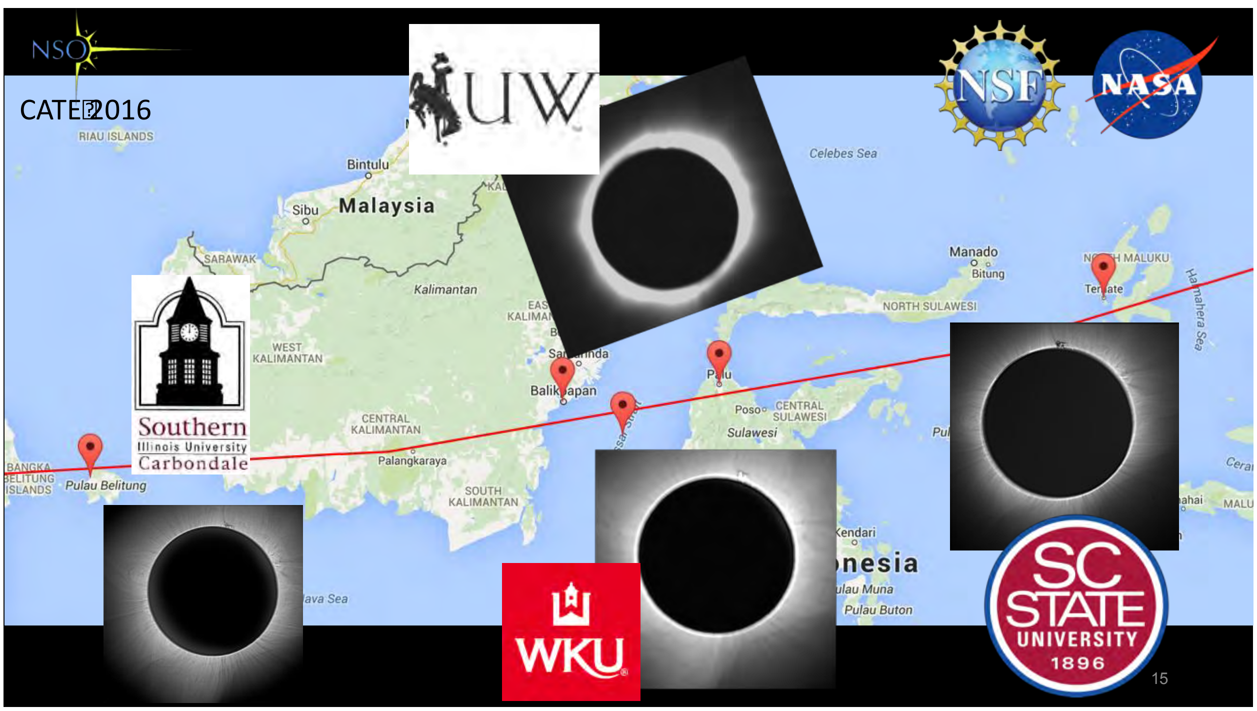


Figure 7.2-1. *Citizen CATE test sites, partners and results from the test run in Indonesia, 2016.*

State coordinators have been identified and are working within the CATE team to ensure adequate observing options for eclipse day. In addition, the Citizen CATE student team has developed a series of instructional videos to prepare local sites in how to conduct their observations on eclipse day. In-person site visits are planned for 2017 to ensure all sites are prepared for their observations on eclipse day.

7.2.2 Know Your Sun: Preparing For the Eclipse Monthly Webcast

Following the 2017 AAS Eclipse Taskforce meeting in Carbondale, Illinois, it became clear that there was a lack of scientific understanding of solar science and the eclipse amongst eclipse event coordinators. In order to address this need, NSO has begun producing a live webcast on the 2nd Thursday of the month between November 2016 and August 2017.

Each month we will cover three topics:

1. **Solar Spotlight**: What do you *really* need to know about the Sun to understand what's happening during the eclipse?
2. **Eclipse Tips**: Learn about some fun ideas to engage kids (and adults!) in eclipse fun, fitting for the run up to eclipse day, and also for the main event!
3. **Straight from the Scientists**: Learn about cutting edge research being done in the field of solar science, straight from the resarchers!

The webcasts will be streamed live on YouTube, and will be archived on both YouTube and the NSO website for those who cannot attend the live event.

The target audience for these webcasts are outreach professionals and event coordinators who are not well versed in solar science. The level of content will be introductory, and designed not only to give people an insight into what will happen during the eclipse, but also to increase general knowledge and interest in daytime solar astronomy. Therefore, the content will contain relevant material beyond the eclipse, and the archive will remain available once the eclipse is over.

Figure 7.2-2. *Clip from webcast promotional video at* http://www.nso.edu/eclipse2017/webcasts

7.2.3 Eclipse Materials

NSO will produce eclipse glasses, postcards, and posters to promote NSO's facilities during the solar eclipse. Eclipse glasses will be distributed to anyone participating in NSO events (see K-12 workshops and public talk series below). In addition, we are working with AURA to distribute the eclipse glasses to Senators along the path of the eclipse, who wish to distribute them to local schools.

Figure 7.2-3. *Possible option for NSO's eclipse glasses design.*

7.2.4 K-12 Professional Development Workshops

Beginning in January 2017, NSO will partner with the Boulder Valley and St. Vrain school districts to provide in-person professional development for local teachers in preparation for the eclipse. There is consideration for videoing these sessions for distribution to Citizen Cate volunteers, though this has not yet been finalized. These will be one-day, weekend workshops held at NSO Headquarters, facilitated by Claire Raftery with assistance from other NSO staff. We are currently reviewing the possibility of two levels of workshop, K–4 and 5–12, in order to better accommodate the needs of participants. The overarching theme will be the eclipse, covering an introduction to the Sun, the magnetic nature of the corona, and how to view the eclipse safely. The workshops will be free of charge, and registration will be handled by the school districts.

7.2.5 Public Talks

NSO, in partnership with other intuitions in the Boulder Solar Alliance (BSA), are deliberating a series of public talks throughout 2017. Each BSA institute will nominate a presenter to give a public lecture on the Sun and the Eclipse each month. Currently, we are planning to host these talks at Fiske Planetarium.

7.2.6 Eclipse Events

NSO is involved in the organization and implementation of two outreach events on 21 August 2017, one in Oregon, the first point of eclipse in the continental US, and one in Wyoming, the closest point to the Denver metropolitan area that is on the eclipse path.

7.2.6.1 Salem, Oregon

NSO, in conjunction with the American Astronomical Society Solar Physics Division (AAS/SPD) will coordinate a public outreach event at Willamette University in Salem, Oregon. This location has been chosen for a number of reasons, including the highest chance of clear skies, the first point of eclipse contact for the continental US, and the proximity to the SPD annual meeting. The coordination with the SPD meeting means that we can expect 100 or more solar physics experts to attend the event, and will participate in outreach activities. We aim to make this the center of solar science on the day of the eclipse.

7.2.6.2 Glendo, Wyoming

Glendo is the nearest point on the total eclipse path to the Denver metro area. The town of Glendo will be hosting a four-day festival around the solar eclipse, with activities, public talks, vendors, and other family-friendly fun. Co-sponsored by NSO, this event will attract thousands of eclipse watchers. This is an excellent opportunity to share the mission and goals of NSO with a broad audience of people.

Figure 7.2-4. *Glendo, WY eclipse event logo.*

7.2.7 Website

The NSO webpage will be undergoing a significant overhaul in the coming year. This is a priority for the OEO, given the popularity of online searches and content delivery by the majority of the population. We will work to develop a modern, user-friendly interface that quickly and efficiently delivers information on the solar eclipse, and other NSO projects in a public-friendly way.

7.3 Hawaiʻi-based DKIST Activities

The Daniel K. Inouye Solar Telescope is a top priority for the OEO. We are currently in the process of recruiting a dedicated EPO staff member who will be based in Maui at the DKIST office. The exact scope of the Maui-based EPO plans will not be finalized until the EPO position has been filled, as we believe that a local expert will be able to bring a better understanding of what is needed. Currently, our existing and anticipated DKIST efforts are as follows:

Current Activities

7.3.1 March 2016 Solar Eclipse

The solar eclipse of March 2016, much like the "Great American Solar Eclipse of 2017", offered a unique opportunity to generate interest for solar astronomy. With the help of our partners, NSO/DKIST orchestrated an extended outreach program on Maui anchored by the partial eclipse. With an eclipse magnitude of 63%, this was the deepest eclipse observable from Maui this decade.

The NSO's Maui Eclipse Art Contest jump started the excitement. A key feature of the contest was the selection of a design to print on 25,000 eclipse glasses distributed to all students across the three populated islands of Maui County. A panel of local experts, from NSO/DKIST, the University of Hawaiʻi Institute for Astronomy, and the Maui Economic Development Board/Women in Technology selected the design. The competition was won by a student from Maui Waena Intermediate School. The art entries were displayed at a public eclipse watch party hosted at Kalama Beach Park by the NSO and the Maui Science Center.

Our project team made visits to classrooms and cafeterias to interact with students across Maui island in the weeks before the eclipse. Award presentations were given at all the schools with awardees from the Maui Eclipse Art Contest. Presentations were designed to be interactive with lots of questions to engage the students. In large group settings, colored pieces of paper were used so that all students could participate in the presentation, which was both effective and fun. We demonstrated how to safely use the eclipse glasses to view the Sun and the upcoming eclipse. The eclipse glasses were not distributed to all students until the day before the eclipse.

7.3.2 Public Outreach

NSO scientists and the Maui Economic Development Board (MEDB) organized 6-8 annual public outreach events, such as career fairs and science festivals. NSO will continue to participate in these events, and increase their involvement with the appointment of the Maui EPO Assistant. NSO scientists have been volunteering at these events since NSO's arrival on Maui. NSO's EPO Officer, EPO Assistant, and local scientists will continue to be involved in these and other outreach activities moving forward.

7.3.2.1 Akamai Workforce Initiative

Akamai is based on a well-supported rationale that the workforce needs of Hawaiʻi are attainable through a modest increase in retaining STEM undergraduates and broadening participation to include more Native Hawaiians, women, and other groups underrepresented in STEM. The program has a lengthy record of success, including long-term retention of >80% of Akamai undergraduate interns in a broad range of STEM degrees and careers. NSO and DKIST partners hosted five of a total of 29 Akamai interns in 2016 coming from a range of engineering and computer science backgrounds. All students were born in Hawaiʻi, with three currently studying in the state, and two studying on the mainland.

Figure 7.3-1. *Akamai Workforce Initiative participants inside the DKIST dome.*

Future Activities

7.3.2.2 Collaboration with Local Cultural Leaders

Working successfully with community leaders and cultural experts will be essential for understanding how best to work with, and interact with local communities. The EPO Assistant on Maui will be responsible for cultivating and maintaining a healthy relationship with local community groups and be responsible for gathering the opinions of the local community and representing them in our EPO efforts as much as possible.

7.3.2.3 Community Involvement

We aim to cultivate an environment of inclusion across NSO and in Maui. We aspire to create an open and welcome atmosphere around DKIST, and to get people inspired by daytime astronomy. One possible program that may move towards achieving this is to hold an art contest in Hawai'i around peoples' interpretation of the Sun. The winners of the competition will have their art displayed at the Pukalani office, DKIST site, and Boulder offices. The exact methods for interacting with the community will depend on the experience of the future EPO Assistant.

7.3.2.4 Development of Classroom Lessons around Solar Astronomy and Hawaiian Culture

During a 2016 visit to Maui, Claire Raftery received significant interest from school teachers around the idea of classroom lessons that bridge connections between traditional Hawaiian knowledge and western scientific ideas. Stories and legends are a vital part of Hawaiian culture, and are playing an important role in how students see themselves. By explaining the roots of these legends through the use of western astronomy ideals, students can begin to see themselves as both Hawaiian and purveyors of the scientific method. As such, we plan to develop classroom lessons that adhere to the Hawaiʻi Content and Performance standards in partnership with local teachers from the Kamehameha School in Pukalani.

7.3.2.5 Teacher Professional Development

Following the completion and successful testing of the classroom lessons above, we will hold teacher professional development workshops for teachers who wish to understand how to conduct these lessons. It will be important that we co-facilitate these workshops with local cultural experts. Hokulani Holt, a native Kumu Hula, has expressed an interest in supporting these efforts.

7.4 NSO-General Education and Public Outreach

In addition to Eclipse and Maui EPO efforts, there are a number of NSO-wide EPO efforts that are underway.

7.4.1 Exhibit Booths at Major Conferences

NSO will continue to attend the annual fall American Geophysical Union meeting in December and is planning to participate in NSF's coordinated exhibit area at the American Astronomical Society meeting in January 2017. In addition, new materials have been developed to promote NSO's mission and science goals for both DKIST and NISP which will be distributed at these conferences in order to increase general awareness of NSO, DKIST and NISP.

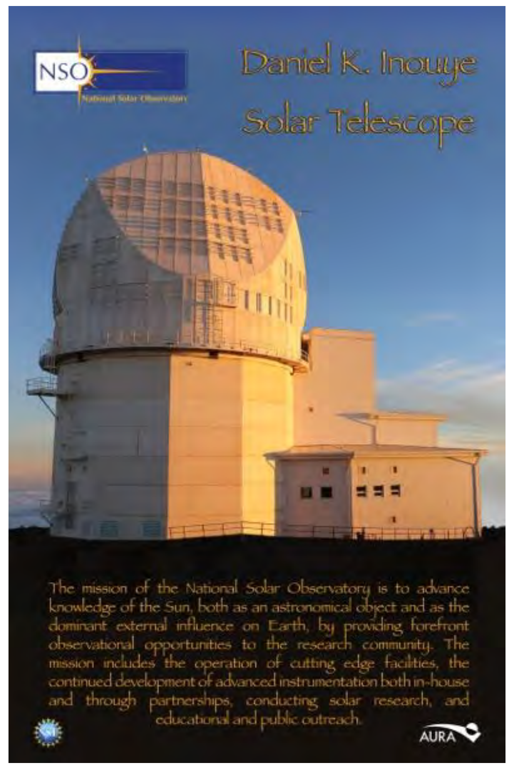


Figure 7.4-1. *Poster for distribution at conferences describing NSO's mission*

7.4.2 REU/Akamai

NSO has had a long-standing REU program running at its Sunspot and Tucson sites for many years. During summer 2016, NSO hosted eight students; four were in Tucson, but the four Sunspot students were relocated to Boulder due to the majority of NSO scientists presence there. The 10-week program was very successful, and has resulted in planned presentations at the AGU and AAS conferences.

From 2017 onward, NSO will be participating in the Boulder Solar Alliance (BSA) REU program, currently led by CU Boulder's Laboratory for Atmospheric and Space Physics (LASP). This program provides a coordinated effort amongst up to eight different solar physics institutions across Boulder. NSO will host between four and eight REU students each year, depending on availability of projects. The BSA REU program has been running for more than a decade, and has an excellent reputation for recruitment of women, with more than 70% of participants being female over the years.

In addition to this excellent recruitment record, NSO has proposed to increase recruitment focus in Hawaiʻi. Given the presence of staff and scientists in Maui, as well as the up and coming opportunities for daytime astronomy, providing focused opportunities for undergraduates to gain experience and interest in solar physics will be beneficial to NSO and the field of solar physics down the line. We have support from UH Mānoa and UH Hilo, as well as from the Akamai Workforce

Initiative principal investigator. They have offered to promote the BSA REU program with their current and former students on our behalf. In addition, the placement of a dedicated NSO EPO Assistant will further broaden our reach into local community colleges and universities.

Although it has not yet been defined, we anticipate that the Hawaiian students who participate in the Boulder REU program will have continued support through our EPO Officer and Assistant on Maui.

7.4.3 NSO Newsletter

NSO's newsletter has been refocused and will begin regular production in December 2016, with bi-annual volumes available electronically. The newsletter will now be focused more on external NSO data users, rather than internal NSO employees as in the past. This will provide a common place for external users to get regular updates on data, science, observing opportunities, requests for observing proposals, opportunities to get involved, and other relevant updates.

7.4.4 AURA e-lithos, Press Releases, and Social Media

The OEO will be responsible for coordinating NSO's input to AURA's e-litho series. We will also work with staff and scientists, in conjunction with AURA and NSF to promote NSO's scientific and technical achievements in the press. Finally, the OEO with support from other NSO employees will continue to maintain and keep current on social media trends and content.

7.4.5 Discovery Channel Documentary about the Sun Featuring DKIST

Radical Media has been contracted by the Discovery Channel to create a documentary focused on the Sun. Following past interviews with DKIST staff for a previous documentary on telescopes, they have chosen to make DKIST a feature of the documentary. They travelled to Haleakala on November 1st to interview DKIST managers about the project. The documentary is expected to be released in spring 2017.

8 NSO TRANSITION UPDATE

In FY 2016, the new Headquarters on the East Campus of the University of Colorado, Boulder (CU-Boulder) became the largest NSO site with 47 of the total 136 NSO employees now Boulder-based. Next year, with continued relocations to Boulder from Tucson and the ramp up of personnel in Maui for construction and operations, Maui will become the second largest NSO-staffed site. FY 2017 is the final year for the relocation of NSO's operations workforce, from historical sites in Tucson, Arizona and Sunspot, New Mexico, to Boulder and Maui. The DKIST construction team will continue to have a presence in the NOAO-managed building in Tucson until the formal end of the project (planned for late 2019). At the end of FY 2017, NSO will discontinue the use of its telescope facilities in Arizona (Kitt Peak) and New Mexico (Sac Peak). The start of the new 10-year Cooperative Agreement (CA) in mid-2015 marked the beginning of this major transformation of the Observatory targeted for the DKIST era.

Early this decade, AURA and NSO decided that the advent of a unique facility such as DKIST could only be fully exploited by drawing the Observatory closer to younger generations of astronomers and engineers. Through an open-call process, the AURA Board in 2011 selected the University of Colorado, Boulder as the new site for NSO's Headquarters, which would serve as the scientific hub for DKIST. CU-Boulder was considered the best location to foster NSO's mission of advancing knowledge of the Sun, both as an astronomical object and as the dominant external influence on Earth. The collocation in Boulder of the two NSO Programs, DKIST and NISP, will also promote the synergies between these Programs and enable common science in ways that have not been possible thus far. In FY 2016, the last of the few scientists based in Sunspot relocated to Boulder, as did six NISP scientists from Tucson. The current pool of scientists in Boulder represents the largest group of NSO scientists residing at the same location in the last decade. The various scientific seminars and activities create a unified concept of the Observatory that sets the stage for our growth. The increased scientific presence at NSO HQ is also making possible fluent and efficient interactions with our partners at the University of Colorado, and with the broader Boulder-based solar community. The practical benefits sought in this long-planned transition are becoming increasingly evident.

In September 2016, the AURA President and CU-Boulder Provost signed the Cooperative Agreement (CA) that outlines the integration of NSO in the University framework and the venues to further collaborations with the research institutions. This CA replaced the previous Memorandum of Intent (MoI) dated September 2012, and is a significant milestone for the transformation of the Observatory. The purpose of the Agreement is to provide a framework within which both parties will advance, through mutually beneficial cooperative endeavors, the respective research missions as related to solar research and educational and public outreach. It is also intended to expand and complement each party's research, education, and service activities, through the promotion of faculty and staff exchanges and the formation of collaborative teams to address specific research and opportunities. The CA states that the NSO is considered an independent research organization rostered under the University Vice Chancellor for Research. The CA consolidates the NSO/CU-Boulder collaboration through the various joint and visiting faculty positions, George Ellery Hale (GEH) post-doc and graduate fellowships, and the appointments of NSO scientists within the University system. Particularly relevant is the status of Research Professor, to which selected NSO scientists can be nominated and makes them eligible for support of activities that are directly pertinent to the research and teaching mission of CU Departments. The expectations are that the Research Professors will become engaged in graduate student advising and mentoring as appropriate; they also may serve on committees of the corresponding areas of interest.

During FY 2016, CU-Boulder has continued moving forward with the GEH Program included in the original bid to host the NSO HQ. As a key component of the GEH Program, CU provides funding for two three-year graduate student fellowships and one two-year postdoctoral fellowship each year (six graduate student fellows and two postdoctoral fellows in residence at any one time). These fellowships are intended to support solar and space physics research and stimulate collaborative activities between CU and the NSO. In exchange for voting rights during the selection process of the postdoctoral position, NSO offered to cover the relocation costs of the GEH postdoc position and provide start-up funding not to exceed a total contribution of $15K. Two members of the NSO staff served on the search committee for the 2016 Hale Postdoctoral Fellow.

FY 2016 saw the successful filling of the first 50% NSO-CU shared tenure-track faculty position. Dr. Adam Kowalski, a graduate of the University of Washington, was selected from a pool of 35 applicants and joined CU-Boulder and NSO in August 2016. The principal employer for this position is CU-Boulder, which provides the salary and the benefits. NSO contributes half of all the necessary funds for this position, including the startup package. A specific Memorandum of Understanding between LASP and AURA/NSO describes the obligations and expectations of the two parties and details the procedure for annual merit review and tenure promotion at both institutions. Having CU-Boulder as the primary employer ensures that the position is well integrated within the academic system of the University and has comparable access to the pool of students as the rest of the faculty. The second, and last, shared position has been advertised and will be filled through a process similar to that in 2016.

The integration of NSO in the academic system of CU-Boulder will have a clear metric of success: the number of students using DKIST data for their research. The GEH fellowships are an essential tool for achieving good rankings in this metric. Some measures have been implemented in FY 2016 to facilitate an environment within which the GEH Fellows can thrive. First, we are initiating a GEH graduate student rotation element to the Program. This GEH research rotation will nominally consist of four half-semester research projects mentored by CU and NSO scientists. These projects can be joint between NSO and CU, or independent. Scientists submit research project descriptions that are presented to the students who choose two for each semester of their first year. At the middle and end of each semester (upon project completion), the students give a short (25-minute) lunch talk on their work to the other GEH Fellows, mentors, and interested scientists. This GEH research rotation will give the students an opportunity to explore research possibilities in a more structured way that enhances the interactions between NSO scientists and the students. Second, a series of monthly solar-focus seminars has been initiated to address specific research topics. The seminars last for 2.5 hours, including a break, during which students socialize with researchers. The seminars typically contain three presentations by scientists from the broader Boulder solar community, with typically one that serves as an introduction to the topic under discussion. The time of the seminars has been selected to not conflict with other student activities. The seminar themes address solar and solar-stellar research in a broader sense. Examples of the proposed themes include spectropolarimetric inversions, helioseismology, flares in the Sun and the stars, and Space Weather predictions.

The third floor of the East Campus' Space Science Building (SPSC) hosts the new NSO Headquarters. The second floor accommodates the Laboratory for Atmospheric and Space Physics (LASP), a research institution affiliated with the three CU-Boulder Departments—Astrophysics, Aerospace, and Physics—that participated in the HQ bid. In FY 2016, NSO completed equipping all office space and common meeting areas on the third floor. Minor improvements will be carried out on an as-needed basis. On the first floor, NSO has a 2,257-square-foot optical laboratory that serves as the staging area for the integration of key components for the commissioning phase of DKIST instruments, including the Visible and Broad Band Imager (VBI) and the high-order adaptive optics (HOAO) system. The DKIST 1600-actuator deformable mirror characterization is currently taking place in that lab. NISP relocated various optical components needed for GONG refurbishment activities to this lab and maintains another fully functional optical lab in Tucson.

At the computer room on the third floor, NSO is already serving data to the community through the Virtual Solar Observatory (VSO). Installation and configuration of the VSO infrastructure required close interaction with the CU-Boulder Office of Information and Technology (OIT) and served as a test bed for the interfaces of the future Data Center (DC) that will distribute DKIST and NISP data to the broader community. Additional IT infrastructure developments have occurred in FY 2016, such as the recent installation of the end-to-end data flow simulator for DKIST. This data simulator is located in the computer room and connects via a 10 GB Ethernet fiber link to the end-user hardware at the remote operations room. This infrastructure will serve as a training center for the DKIST operators. The NISP Data Center was slated for its relocation to the first floor of the SPSC building in the third quarter of FY 2016. CU OIT has delayed the process due to space constraints as other CU-Boulder institutions also use this space. The transfer of the NISP DC is now scheduled for February 2017, and CU OIT has communicated that all logistical problems have been sorted out with no further delays expected. Accordingly, the NISP DC will start serving its SOLIS and GONG 6-8 TB/month derived data products from the CU-Boulder network in the second quarter of FY 2017. The total amount of archival data offered by the NISP DC nears 1 petabyte (PB). Discussions on the networking architecture and firewall policies implemented for the NISP DC will benefit the DKIST DC ramp up in the upcoming years.

NSO is consolidating IT services in Boulder using 3.5 FTEs distributed among DKIST (1.75 FTEs), NISP (0.5 FTEs), and NSO (1.25 FTEs). A senior IT position will dedicate 25% of his/her time to manage Observatory-wide IT needs with the help of one additional FTE. Examples of the IT-team tasks are the NSO's web and e-mail (*@nso;.edu)* servers, AV equipment maintenance, users' authentication for various services including scientific support, home directories, and backups, support to the Director's Office, and point-of-contact with CU OIT. The remaining dedicated tasks within the respective NISP and DKIST Programs (2.25 FTEs) will cover areas such as scientific computational needs and desktop support. This restructuring of the IT services in Boulder requires the relocation in FY 2017 of two IT personnel, one from Sunspot and the other from Tucson.

In Maui, the DKIST construction workforce continues to increase at the expected pace. About 32 NSO employees are residents on the island. This trend will continue in FY 2017 when it reaches the maximum number of construction FTEs. The ramp up for operations, however, is moving at a slower pace than the staffing plan presented in the Cooperative Agreement proposal. The delays in the availability of the Remote Office Building (ROB) have prevented NSO from increasing the operations workforce at the pace described in the original CA proposal. Only two scientists that are part of the operations workforce are currently on Maui. We are expecting an additional three operations FTEs in FY 2017, including the EPO Assistant who will report to NSO Head of EPO Dr. Claire Raftery. In FY 2017, NSO will have to continue using the University of Hawaiʻi Institute for Astronomy (UH/IfA) ATRC building in Pukalani to provide office space for the DKIST operations team.

The Remote Office Building, to be located at Pukalani, will serve as the off-summit center for day-to-day operations of the DKIST. The ROB will provide workspace for the scientists and post-doctoral researchers, engineers, technicians, off-site services personnel, and administrative staff that do not require daily access to the DKIST observatory site. In late FY 2016, NSO made significant progress with the ROB in two areas. An Environmental Assessment process conducted by AURA after NSF approval was successfully concluded in spring 2016. After this authorization, the Observatory moved forward with requesting the necessary construction permit that's expected during the first quarter of FY 2017. In parallel, NSO also issued a Request for Proposals for the building of the ROB and received five bids that were analyzed by a source selection committee. The final recommendation from this committee has been presented to the Solar Observatory Council (SOC) and to the AURA Board, which approved the selection in late November 2016. The building of the ROB is expected to start in the second quarter of FY 2017 and last for about a year. Once the ROB is available, NSO will relocate operations personnel to Maui from Boulder and Sunspot.

NSO presence in Tucson and Sunspot is ramping down according to the plans described in the Cooperative Agreement. Both sites have seen in FY 2015 the redistribution of office space as dictated by various needs. In Sunspot, most of the office space now resides at the Dunn Solar Telescope (technical team and observers) and the Community Center (administration). The Visitors Center continues to receive about 15,000 visitors each year and maintains its schedule as in the past.

In December 2015, a winter blizzard severely affected the Sac Peak site. Registered snowfall during the storm reached 18 inches on December 26th and 27th. Wind gusts were recorded at over 94 miles per hour prior to the wind gage breaking at the DST. The site had about 50 downed trees and power lines including fallen trees on three residences. The A-frame building owned by AURA was severely damaged. Damage assessment revealed multiple water leaks in several on-site buildings. The water system was shut down, and all boiler systems in all buildings turned off. Downed trees blocking the roads prevented full-site access, and the site was without power until January 4th. The majority of the staff living onsite were relocated to hotels in Alamogordo and returned to regular work on January 5th. There were no personnel injuries. The DST was safely shut down and brought back to full operations once power and water services were restored. The site repairs, mostly electricity and plumbing, generated an extra cost to the Observatory of $95K.

The NSO office space transfers in Tucson continue to be driven by the Large Synoptic Survey Telescope (LSST) ramp up in the NOAO building. NSO has relinquished most of the offices in the building with a few exceptions. Most notably, the hallway with the NSO Director's office in Tucson was transferred to LSST in FY 2016. The remaining NSO offices—apart from the DKIST construction team offices at the NOAO penthouse—are concentrated at the northeast corner of the building, where a few scientists and the SOLIS relocation team operate. The NISP Data Center will continue to operate in the DMAC building until the first quarter of 2017, when the DC hardware is scheduled for relocation to Boulder. There will be no presence of NSO base-funded personnel in the AURA buildings in Arizona at the end of FY 2017.

Attrition in both Sunspot and Tucson remained low in FY 2016. Two factors have contributed to these low attrition levels. First, most of the personnel with the intention of seeking jobs elsewhere already did so in FY 2015. Second, the retention policies implemented by NSO management have helped prevent further losses at both sites. The loss of two observers at the DST in FY 2015 was remedied with two new observers who will eventually join the DKIST Program full time. Their current location is Sunspot, where they participate in the necessary training in solar observations under the guidance of the DST Chief Observer. In Tucson, the most senior observer for the McMath and SOLIS has retired, but his tasks were reassigned within the NISP team.

Table 8.1. Dunn Solar Telescope Personnel Ramp-Down Profile (FTEs)

Year	Scientists	Observing Support	Technical Support	Operations
2014	3	3	5	Full
2015	3	3	5	Full
2016	1	2	3	5 days/week
2017	1	2	2*	5 days/week

**Support from part-time employees exists.*

In FY 2015, the DST operations model was modified to make it compatible with the transformation of the Observatory. The reduced operational workforce at the facility made weekend operations impractical (see Table 8.1). Although quarterly calls for proposals are still made, the Telescope Time Allocation Committee (TAC) determines the exact amount of observing time available each quarter after evaluating proposal pressure, personnel vacation needs and other factors. In FY 2015, the total time offered to the community represented only 50% of the available time. While this accounts for a significant reduction of the offered time (typically about 85%), the total time successfully used by the community has been reduced by only 10% compared to previous years. This small reduction in the time successfully used at the telescope is the result of longer periods of scheduled downtime used for more frequent maintenance. Thus, the unscheduled downtimes due to technical problems have been kept at historically low levels (a few percent).

The DST is a key training facility for the DKIST operations workforce. The premature loss of the facility will not only impact the community, which will lose the most highly equipped solar telescope in the US, but it will also steepen the learning curve for the operations team in Maui. The three observers in residence at the facility provide user support at the DST while at the same time develop observing plans and documentation for DKIST operations. NSO remains fully committed to keeping the DST operational through FY 2017.

8.1 The NMSU-Led Sunspot Solar Observatory Consortium (SSOC)

One of the mandates described in the NSF Request for Proposals to renew the NSO Cooperative Agreement was the divestment of the DST approximately two years prior to the commencement of DKIST operations. The RFP explicitly requested a plan to reduce the operational cost of the DST by the end of FY 2017. In this context, NSO and the Astronomy Department of the New Mexico State University (NMSU) over the past few years have been studying ways to establish a consortium that operates the facility after the departure of NSO. NMSU already manages the neighboring nighttime Apache Point Observatory (APO) and is familiar with the needs associated with operating an astronomical facility in the Sacrament Peak area. In FY 2015, NMSU submitted a proposal to the State of New Mexico Higher Education Department. The proposal was ranked as having top priority and received support from various State authorities. Securing funding for the proposal, however, was prevented due to State of New Mexico financial constraints related to decreasing oil prices. This outcome forced NMSU, after consultation with the relevant stakeholders, to explore other funding possibilities. The goal has always been to form a university consortium that operates the DST for at least five years. But it was clear that for the consortium to succeed, an overlap period with NSO was needed to transfer the necessary knowledge and expertise. The negative news from the State of New Mexico caused the urgency of finding an avenue for NSO to train NMSU before a full transfer to the consortium occurs. In this context, NMSU submitted an unsolicited proposal to the NSF/AST for two years of support, starting in FY 2017, when NMSU would hire new personnel and train them while NSO is still present on-site. The proposal also had a decided science focus. The DST will remain competitive as DKIST operations unfold in Maui. As in other areas of astronomy, smaller and older telescopes change focus and routinely perform follow-ups from the discoveries made at top-notch facilities. Similarly, here, the DST could develop synoptic programs where a relatively large aperture and high sensitivity instruments are needed. Examples cited in the NMSU proposal were the tracking of solar filaments and flare prone active regions. Under these premises, the proposal submitted to the NSF was approved and the needed funding secured for NMSU to hire new personnel that can be trained by the NSO staff. In parallel, NMSU continues the conversation with the State of New Mexico to seek long-term support for the university consortium after this initial two-year period.

NMSU has recently advertised three positions that will join the Sunspot workforce in early 2017 and start the on-site training experience. Two additional job ads will follow suit. These new employees will form the core of the operations team that will operate the facility in 2018, after NSO's departure. The positions are:

1. A telescope systems engineer in charge of the telescope control system, its documentation, and potential modernization.
2. A software engineer responsible for the IT infrastructure at the DST and at other locations on-site such as the microwave radio link that provides overall internet connectivity.
3. A telescope operator in charge of learning and documenting observational procedures at the DST.
4. An adaptive optics specialist to renew the existing AO system with modern, simple, readily available components.
5. A facilities site engineer who assumes full control of a much-reduced site.

Except for the AO specialist, NSO has personnel on-site with similar responsibilities that will facilitate the training of the NMSU team. For the renewal of the AO system, a collaboration that includes DST staff familiar with the existing AO system, the NMSU Electrical and Computing Engineering School, and the NMSU Astronomy Department has been established to narrow down the scope of the project. The DKIST AO team has offered support on an as needed basis. NSO Emeritus Astronomer Richard Radick is leading a strawman design that will be available for discussion in the second quarter of FY 2017.

The NMSU team will have only one year to interact with the NSO staff. This limited time is considered marginal at best and an extended period would be desirable. The CA proposal discussed the involvement of NSO in the early phases of the transition of the facility to a university consortium. In this context, and to help secure a successful transition to the NMSU-led consortium, NSO is considering offering to key employees one additional year at the facility with remote-worker status following AURA policy (see section 8.6). The NSO's financial commitment in this regard will be considered a net contribution to the consortium and compensated in the form of guaranteed observing time at the DST.

Approval of the NMSU two-year bridge proposal has sparked some interest from potential consortium partners who have formalized an initial commitment in this early phase. CU-Boulder will contribute $50K each year. Their primary interest lies in education through a summer workshop-series program for graduate students. These workshops might be formally included in the COLLAGE distant learning course and serve as a hands-on component of the graduate program. The California State University, Northridge (CSUN) has consolidated a similar contribution but with a focus on instrumentation development and scientific research. Other potential consortium partners are the University of Hawaiʻi, High Altitude Observatory (HAO), and the Astrophysics Research Corporation—the managing institution of APO—that includes partners with interest in solar physics such as Georgia State University and the University of Washington. The University of Hawaiʻi and HAO are interested in both developing and leaving their instruments at the DST. The Consortium has expressions of interest from international instrument partners from the UK and Italy, and potential financial interest from the Chinese Academy of Sciences.

The baseline operations plan that NMSU has established includes running the telescope in synoptic mode at ~40%-time with limited setup, at ~40%-time made available to PI-led projects, and at ~20%-time for maintenance and upgrades. The cost of such operations is expected to be about $100K per month. The synoptic mode observations will be made available to the entire community and will likely concentrate on unique space-weather relevant data for which a large aperture (compared to GONG) is needed. The vision of the SSOC is to operate the DST in FY 2019+ with 9 FTEs at an annual estimate of ~$1.1M.

Availability of the DST during DKIST operations ramp up and consolidation is essential in a number of ways. First, it will allow for continued training of NSO operations staff at the DST thanks to a suite of instruments that closely resemble the DKIST first-light instrumentation. Second, it will make available an excellent platform to support future prototype testing as needed for the second generation of DKIST instrumentation. Lastly, in the era of increased awareness about the adverse effects of space weather, the availability of a capable telescope such as the DST can prove crucial to implement monitoring programs difficult to perform at facilities in high demand.

In parallel with the efforts of the consortium, the NSF has started an Environmental Impact Statement process to evaluate potential environmental impacts associated with proposed changes to operations. The process is expected to end during the fall of 2017.

8.2 The McMath-Pierce Solar Telescope

Progress with the parties interested in operating the McMath-Pierce Solar Telescope (McMP) after FY 2017 has been slower than desired. The bottleneck has been the inability to identify a partner with the administrative backbone in place that's needed to lead the consortium. Currently, the contributions to McMP operations originate from individual scientists interested in the unique capabilities of the telescope—primarily its photon collecting power in the thermal infrared. In FY 2017, NSO funding for the McMP barely covers the NOAO Joint Use Fee and the part-time observer's salary. Under these circumstances, the telescope will be operational only for requests from scientists who have contributed in the past to support operations of the facility.

Unfortunately, the possibility of building a consortium around the Tohono O'odham Community College (TOCC) has disappeared. In July 2016, the TOCC Board of Trustees informed NSO that they have decided to not pursue future operations of the McMP. Other potential sources of revenue that NSO has been exploring, such as the Northrop-Grumman Starshade experiment, has not received new funding and therefore are not expected to provide support for McMP operations in FY 2017. Under these circumstances, we have started a conversation with the NSF about the potential closure of the facility and the impacts of such a decision. A final solicitation of interest to the astronomical community is also being evaluated.

8.3 Transition Timeline, FY 2017 Milestones, and Transition Risks

The CA proposal explains the timeline for NSO's transition (see Figure 8.3-1). In this section, we present an update on the status of the various milestones. Three major guidelines included in the Request for Proposals from the NSF dictated the timing for NSO's transition milestones. These guidelines are part of a recommendation of the 2012 Portfolio Review Committee to the NSF/AST and are:

- The end of DST and McMP operations by late 2017.
- A decrease of the NSF/AST contribution to the NISP budget to $2M by FY 2016.
- The beginning of DKIST operations in 2019.

FY 2017 is the second year during which the NISP budget remains at the $2M level. In FY 2016, however, the Program was provided with a one-off contribution of $2.5M from the NSF to refurbish the GONG network. FY 2016 also has seen the consolidation of NOAA's contribution to GONG operations at a level similar to past Air Force support ($800K). These contributions are part of the National Space Weather Strategy and Action Plan and allow for a softer adaptation to the reduced budget. The scope of the GONG refurbishment and budget implications are explained in Sections 6.1 and 9.2.3, respectively. The NSO transition is impacted by this activity, which was not part of the original plans. Personnel dedicated to GONG refurbishment and new hires needed for this activity are distributed between the Boulder and Tucson sites. This separation of workforce is slowing the progress in some areas of the refurbishment project that currently will likely extend well into FY 2018. In addition, there are other NSIP milestones that are also progressing at a slower place than originally intended. These are the new site selection for SOLIS in the first quarter of FY 2017; the NISP Data Center relocation to the SPSC building in Boulder by February 2017; and the relocation of the GONG engineering units in the second quarter of FY 2017. The delays are partly due to the loss in FY 2016 of the NISP Program Manager.

For SOLIS relocation, two sites remain under evaluation: Big Bear Solar Observatory (BBSO) in California and Sunspot, New Mexico (proposed by NMSU). NISP has expressed a clear preference for the BBSO site, given the superior synoptic quality of the skies compared to the monsoon-affected conditions at Sac Peak. The California site is also closer to Hawaiʻi, allowing SOLIS to effectively act as a context imager system for DKIST (a recommendation of the NSF/AST Portfolio Review Committee). The selection decision has been delayed (for about a year) due to the process of clarifying what permits are needed to relocate SOLIS to Big Bear Lake and the environmental studies that may be required. While significant progress has been made, at the time of this writing, NSO is still awaiting additional information from the San Bernardino County before a final decision can be made.

Moving SOLIS to its final site will be the last activity NISP will coordinate from Tucson, where the instrument is currently located.

The DST scientific operations team is Boulder-based. One FTE (see Table 8.1) is allocated for on-site scientific support that is split among three scientists, with the DST Lead Scientist Han Uitenbroek allocating the largest share of his time (75%) for facility operations. Starting this year, the DST will offer on-site scientific support only to those proposals that explicitly request it. For these requests, a scientist will move temporarily from Boulder to Sunspot.

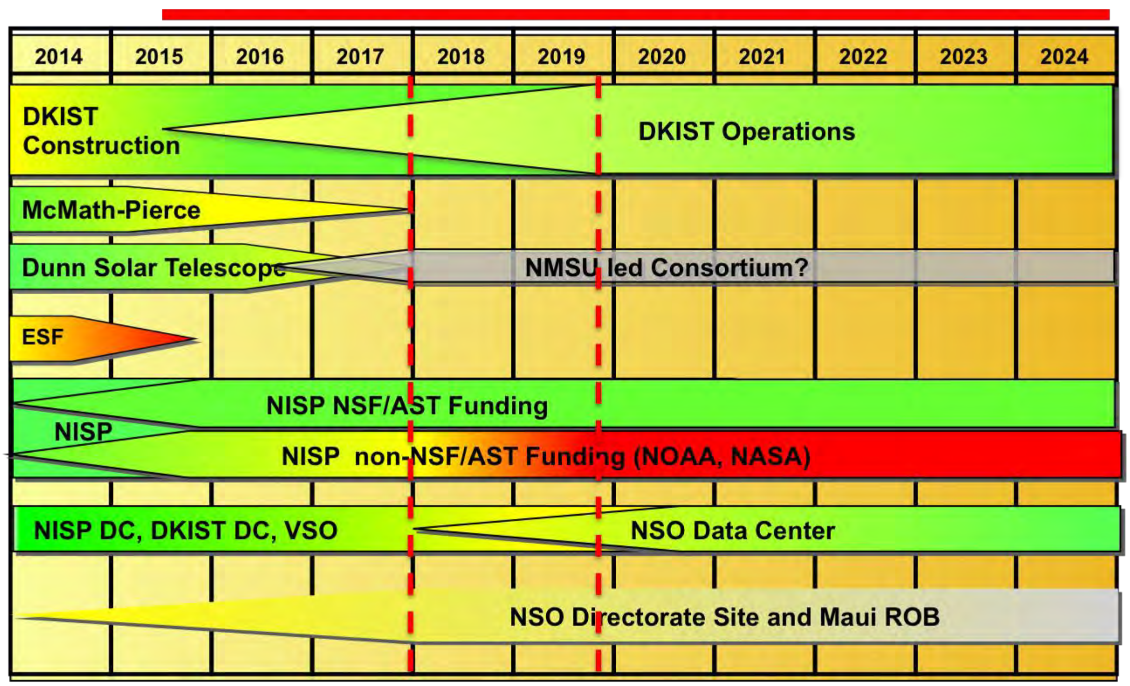


Figure 8.3-1. *NSO transition timeline and major milestones (red dashed lines).*

The ROB delays have impeded the expected growth of the operations team in Hawai'i. These delays represent a major obstacle for consolidating the operations workforce. By mid-FY 2017, we are expecting to have a total of four FTEs—including one Educational and Public Outreach (EPO) position—on the island, all located within the UH/IfA ATRC building. This staff represents a minimum workforce that is necessary for optimizing our collaborations with the instrument partners on Maui and for disseminating the scientific and societal benefits of the DKIST facility. A larger operations workforce, however, was initially planned for this phase of the telescope construction. The CA proposal's staffing plan includes 10 FTEs for operations in Maui at the end of FY 2016. This larger workforce has not materialized because of the ROB delays. As the ROB nears completion, NSO, in collaboration with AURA/HR, is planning for an efficient transition process that allows proper phasing of the operations workforce ramp up with the end of construction of the facility at the summit.

In Table 8.3-1, we outline in green the transition milestones that have been successfully achieved, and in orange those that have suffered a delay of about one year. The two most significant milestone delays are the ROB construction and the SOLIS site selection.

Table 8.3-1. Transition Milestones*

	2014	2015	2016	2017
NSO HQ	• Lease with CU-Boulder signed (LoI). • NSB Action Item • Director is Boulder-based • Sac Peak Site Leader • Transition Plan Draft	• New CA starts • Tucson Site Leader • Update Transition Plan • 3rd-floor remodeling starts • 3rd-floor inauguration • NSO Sac Peak moves	• Update Transition Plan (Q1) • Continue moves from NSO sites (Q2-3) • Library relocation (Q1) • CA signed with CU (Q2-3) • Decision on NMSU consortium (Q2-3)	• Update Transition Plan (Q1) • Continue moves from NSO sites (Q2-3) • Decision on McMath (Q3-4) • NSO base-funded presence in Tucson ends (Q4) • Transfer of Sac Peak operations to NMSU (Q4)
DKIST	• DCPM hired • DKIST AD is Boulder-based	• Operations funding wedge • DC core team formed • First science position, Maui • WFC team starts relocation	• Support & operation teams in Boulder/Maui build up (Q2-3) • Continue moves of science team to Boulder/Maui (Q2-3) • ROB construction approved (Q3)	• Support & operation teams in Maui build up (Q1-4) • Continue hires in Maui (Q1-3) • DKIST ops is Boulder-based (Q2) • ROB available (Q4)
NISP	• SOLIS relocates from KP to Tucson • SOLIS overhaul starts	• SOLIS RFP announcement • NISP scientific staff relocation starts • NISP AD relocates to Boulder	• Relocation of NISP DC starts (Q2) • SOLIS site selection (Q2) • NISP scientific staff relocation (Q2-3) • Relocation of GONG engineering unit starts (Q4)	• SOLIS relocates to final site (Q4) • NISP DC in Boulder (Q2) • Relocation of GONG engineering units (Q3) • NISP is Boulder-based (Q4)

******In green are the milestones that have been fully achieved; orange, those that are postponed by a year or less; and in black, those that are unchanged with respect to the previous year.*

Table 8.3-2 summarizes the identified Observatory risks, all related in various ways to the transition, and their potential mitigations. It is a summary of a more thorough risk register for NSO's operations that uses the AURA provided simplerisk tool (*https://aura.simplerisk.it/*). Note that this table does not address directly the DKIST construction risk register that manages the project contingency. This table represents an update of what was included in last year's Annual Program Plan. The second column (Likelihood) provides the probability of occurrence and the third (Impact) the severity of the various risks, both following a five-grade scale. The most severe risks identified (ranked at 6 or higher) correspond to (a) losing key staff, in particular, top level managers and cost-account managers; (b) potential funding shortfalls in the DKIST operations funding ramp up; and (c) the ROB delays. The first risk (rank 8) primarily arises from the wearing out of personnel involved in the development of a state-of-the-art facility while, at the same time, the Observatory is executing a rather complex transformation. The second risk (rank 6), funding shortfalls, impacts various aspects of the operations scope and has the Data Center as the most critical element. We note that the design of the DKIST data calibration and distribution system started only about two years ago, and was not included in the original MREFC scope (unlike the LSST case). While other similar facilities dedicate fractions for their data systems of about 20% of their total cost, the DKIST Data Center percentage budget is in single digits. A budget shortfall of about $6M over the ten years of the CA award has been preliminarily identified, given the current scope definition of the Data

Center. This Data Center definition will go through a Conceptual Design Review in the second quarter of FY 2017. As part of the Data Center scope, the inclusion of data products that go beyond instrument calibrations will require additional resources.

Table 8.3-2. NSO Operations Risks and Mitigation Strategies (10/16)				
Risk[1]	**Likelihood[2]**	**Impact[3]**	**Implications**	**Mitigation**
Losing key staff 8	5 (↓)	4	Delays in transition to Operations. Degraded services	Communications. Internal promotions. Re-hire vacancies
Insufficient budget 6	3 (↑)	5	Delays in transition to Operations. Degraded services (Data Center).	Operations scope negotiation with stakeholders. DKIST visibility (AAS, etc.)
Maui workforce (ROB delays) 6	5 (→)	3	Workforce buildup delays. Impact on the transition to Operation.	Budget re-profiling. Extended NSO presence in Sunspot.
Staff disengagement 4.8	4 (→)	3	Decreased productivity. Degraded services.	Communications plan. Top-level manager's engagement. Bonus strategies.
Reduced service at critical facilities 4.8	3(→)	4	Fewer observing days/data products offered to the community.	User's Committee involvement.
Sunspot divestiture 3.6	3 (→)	3	Training of DKIST operations staff. DKIST instrumentation development.	Collaboration with potential partners (NMSU).
Integration in CU-Boulder 3.2	2 (→)	4	DKIST community user base not growing	Improved students flow. Progress with CU Agreement.

[1]Risk=Likelihood×Impact×4/10. Maximum risk is 10.
[2]Likelihood: 1 less probable and 5 most probable. Arrows mark trends: increasing (↑), stable (→) and decreasing (↓).
[3]Severity: 1 less severe and 5 most severe.

At the historical sites in New Mexico and Arizona, the transition is impacting staff morale. The biggest concern continues to be maintaining our ability to operate the DST with a reduced workforce until the end of FY 2017. Two factors are helping us to achieve this goal. Firstly, our workforce received very positively the announcement of the NMSU proposal approval. Secondly, NSO and AURA/HR have implemented a series of retention bonuses to help motivate employees to stay with us until the end of our mission at Sac Peak.

8.4 FY 2017 Staffing Plan

Currently, there are 30 employees in Maui for DKIST construction and two scientists hired from the operations funding wedge. NSO is opening a third scientist position in Maui and an EPO Assistant will join the workforce in early 2017. Further hires for operations in Maui, up to a total of four, will depend on progress with the ROB. A large number of relocations and new hires will occur in FY 2018.

The staff in Boulder represents a mixture from the DKIST Construction Project and NSO's base-funded employees. Eleven new hires are expected to occur in Boulder. NSO has restructured the business area with two Business Managers, one for the DKIST Construction Project (Rex Hunter) and a Boulder-based Manager to be hired in 2017 for NSO Operations. This Business Manager for operations will be in charge of the budgeting process through the WEBUD tool, yearly expenditure tracking, and financial reporting to the NSF. The DKIST Data Center will continue ramping up its personnel, adding three staff to support the Data Center and the operations tool development. Three postdoctoral positions will open in FY 2017 to provide support to those scientists whose service dedication—in particular to the DKIST Project—is impacting their personal research. We also plan to hire engineers that support the second generation of DKIST instruments, in particular, MCAO development.

For FY 2017, NSO is planning to open the following positions (contingent on approval of the requested budget):

1 Business Manager. Boulder-based. Application.
1 Administrative Assistant. Boulder-based. Appointment/Application.
2 DKIST Data Center positions. Boulder-based. Appointment/Application.
1 DKIST operations tools position. Boulder-based. Appointment/Application.
1 Instrument Project Manager. Boulder-based. Appointment/Application.
1 Instrument Engineer. Boulder-based. Appointment/Application.
1 IT Manager. Boulder-based. Appointment/Application.
1 Operations Scientist. Maui-based. Application.
1 Education and Public Outreach Assistant. Maui-based. Application.
1 IT support position. Maui-based. Appointment/Application.
1 Operations support positions. Maui-based. Application.
3 Postdocs. Boulder-based. Application.

Job descriptions for these positions are being made available through the NSO intranet and the AURA job register as they become available. Applications are initially posted internally for a week for the NSO staff, and if no internal candidates are identified, the positions become publicly available.

Including the two newly hired observers for DKIST, there are 21 FTEs in residence in Sunspot. We do not expect this number to decrease significantly until the end of FY 2017 when employee transfers to Maui and terminations will occur. One additional transfer to Boulder takes place in FY 2017. Five new NMSU positions will join the NSO workforce on-site.

In Tucson, NSO has 36 FTEs, with 16 employees for DKIST construction and 20 for operations, mostly part of the NISP Program. The DKIST construction staff will continue to use the office space in Tucson until the end of the project. Nine relocations from the NISP team to Boulder occur in FY 2017, with a first group formed by the remaining scientists of the Program and a second one formed by the SOLIS engineering team. The rest of the NSO staff will either retire or continue as remote workers (see below).

The organizational chart (Figure 8.5-1) provides an update on the expected FTEs allocated to each of the NSO programs in the stable phase for operations after DKIST first light. The numbers for NISP are based on certain assumptions about future grant support obtained by the Program.

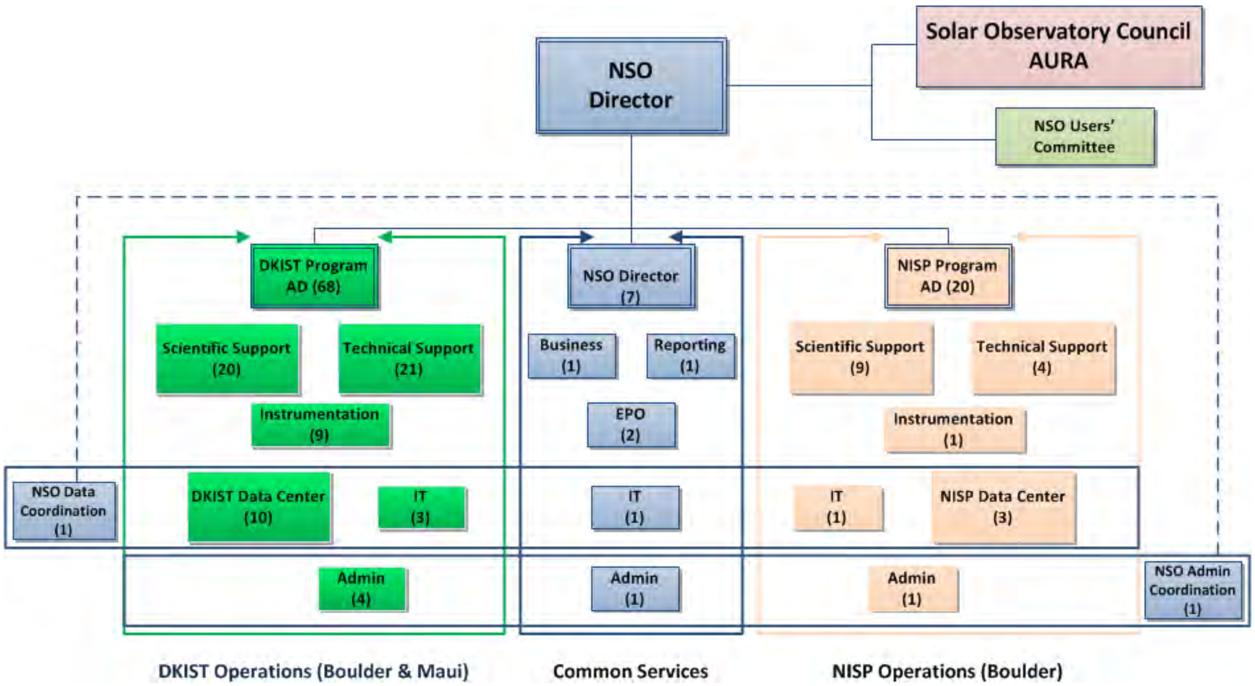


Figure 8.5-1. *Expected distribution of FTEs (in parenthesis) for NSO in the operations phase. This chart is a tentative diagram that is still being discussed at various levels within the NSO Directorate and Programs.*

8.5 FY 2017 Transition Budget

The three-year transition budget was explained in the CA proposal and the FY 2015 Program Plan. Here we provide an update on the transition expenses planned for FY 2017 that cover the following:

- The relocation costs for personnel who move to Boulder/Maui and new hires at those sites.
- Accrued vacations and the benefits packages for personnel that disengage from NSO.
- The cost of moving equipment and goods to Boulder/Maui.

All furniture and IT/AV equipment for the third floor is already in place with no additional costs planned for FY 2017. We note, however, that office space in Boulder already is becoming tight and minor remodeling of cubicle areas is being discussed with CU-Boulder.

A total of 11 hires are expected to occur in Boulder and 4 in Maui (see staffing plan). The cost of the new hires includes position advertisements, interviews with the shortlisted candidates, and relocations after selection. A total of $218K has been allocated for these hires. In FY 2017, we are expecting our IT person in Sunspot and nine employees from Tucson (all NISP-related personnel) to relocate to Boulder. As discussed during the CA negotiations, the relocation budget covers house-hunting trips, moving of household goods, actual travel during the final relocation, and a small amount for hotel expenses. These relocations all follow the applicable AURA policy available on the NSO intranet. The corresponding budget for Boulder relocations in FY 2017 is $148K and follows historical guidance from previous year moves. We also include in the budget a total of 10 relocations to Maui with a cost of $200K. These relocations were proposed in the original transition plan, and some should have occurred already. Due to the ROB delays, it is clear that these funds will have to be carried forward to FY 2018 when the actual relocations occur.

Moving equipment from Sunspot and Tucson to Boulder is budgeted at $60K, which includes components from the machine shop in Sunspot; the GONG engineering units; optical hardware from Sunspot and Tucson, including reference flat mirrors and optical tables; IT and AV equipment; and documentation from the offices at both sites. The final disposition of costs for the two locations are not yet fully defined and require discussions with the NSF.

September 30, 2017 signals the end of NSO operations presence in Tucson and Sunspot. Some of our employees at both sites are impacted by this.. NSO has negotiated with AURA/HR a benefits package that is offered to those employees going into retirement or being terminated. Following the examples of other transitions that included Reductions In Force (RIFs) at other AURA centers, and using AURA policy guidelines, all impacted staff have been notified in person one year in advance of their expected completion of employment and of their corresponding benefits package. The total cost associated with the RIFs at the end of FY 2017 is estimated to be $232K.

8.6 Relocation Policy Changes

Minor modifications to the relocation policy occurred in FY 2016. Those changes relate to clarifications that are explained in the corresponding revision summary. The modified policy can be downloaded from the following password-protected link:

http://www.nso.edu/sites/www.nso.edu/files/u161/NSO%20HQ%20Relocation%20Policy.pdf

As announced in last year's APRPP, a teleworking and remote working policy is now in place. The policy follows similar guidance used at other AURA centers. That document is available at:

http://www.nso.edu/sites/www.nso.edu/files/u161/AURA%20Teleworking%20and%20Remoteworking%20policy%20and%20procedure.pdf

With this policy, NSO recognizes the importance of supporting its employees' balance of work and home life by offering flexible working arrangements. Remote working is an aspect of teleworking whereby employees may perform their regular job responsibilities away from their primary office locations, for a period up to 100% of each workday. Remote Working will be considered in exceptional cases only, such as where NSO needs to employ highly specialized technical skills, or where NSO is involved in significant collaborations with other institutions.

8.7 Communications and Staff Feedback

Communications with the NSO staff have continued along the lines described in last year's Program Plan with slight modifications. Instead of all-hands meetings involving all four NSO sites, we have moved to a model with specific informational gatherings at each of the impacted sites. This model better serves the transition at this stage, as it was clear that at times the information pertinent to one site may be less relevant to another site (e.g., the NMSU proposal was relevant to Sunspot but less so for the Tucson staff). During FY 2016, three such meetings were held in Sunspot and one in Tucson. A summary of the status of the NSO transition was presented at the DKIST all-hands in Maui. The topics presented at these meetings were the remote working policy, the benefits package at the end of employment, retention bonuses, etc. At the last meeting with the employees in Sunspot, the PI of the NMSU proposal, Dr. James McAteer, was invited to present the Consortium plans for FY 2017/18. NSO and Apache Point Observatory staff also attended the meeting.

A second series of one-on-one interviews occurred in FY 2016. These interviews took place before AURA/HR submitted to all employees a letter informing them of our plans at the end of FY 2017. All impacted employees met with their respective supervisors and a representative from HR. The interviews were used to confirm each person's future employment status and to discuss potential options in the few cases where employees modified their original intentions. The transition website, *http://www.nso.edu/relocation,* continues to be updated with information about relocation policies, new open positions, and the transition schedule. The online anonymous feedback form for NSO staff continues to be available, and the FAQ was updated after the one-on-one meeting series, primarily addressing HR-related concerns.

9 FY 2017 SPENDING PLAN

The NSO spending plan is based on receiving the President's FY 2017 Budget Request of $17.5M for NSO, excluding a one-time contribution of $2.5M received in FY 2016 to partially fund the Remote Office Building (ROB). The NSO budget presented here follows the guidelines in Table 8.4-2 of the Cooperative Agreement proposal submitted by AURA in October 2013.

Figure 9.1 describes the organizational structure of the Observatory and includes all of the Cost-Account Managers with financial responsibilities. Red lines in the chart correspond to the DKIST construction project.

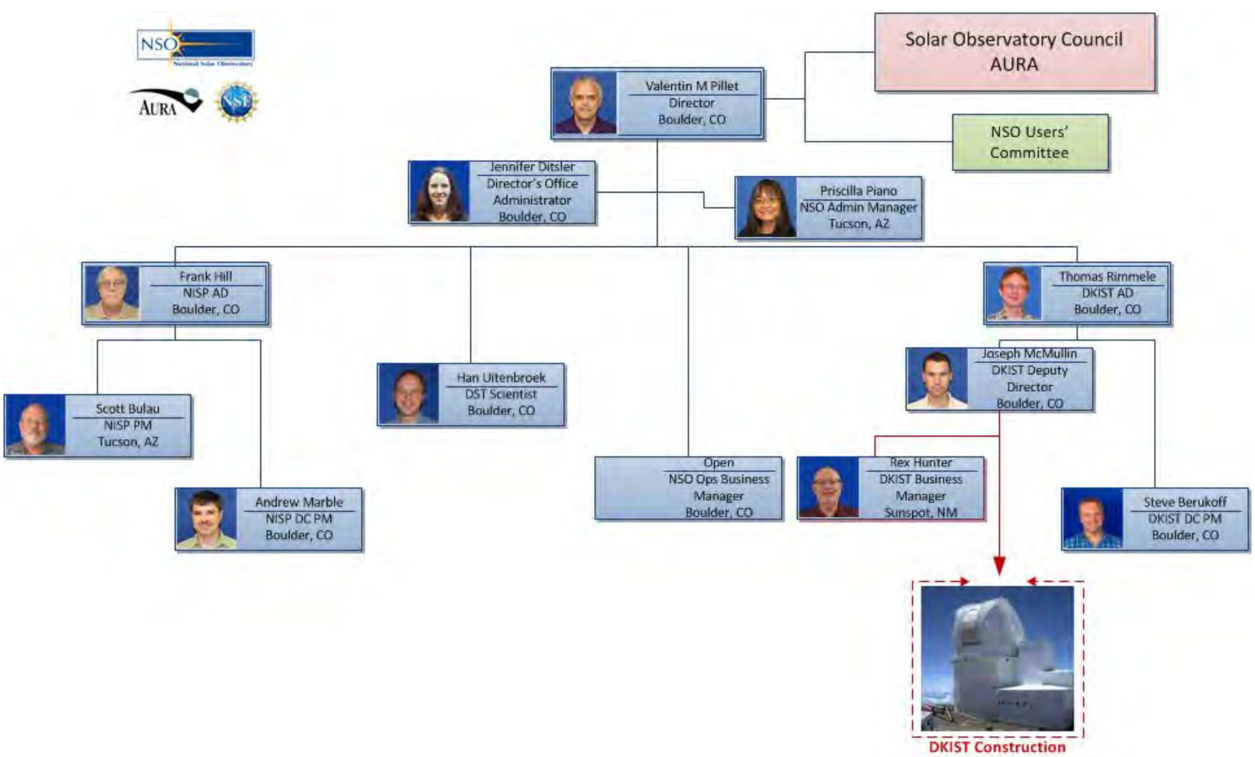


Figure 9.1. *NSO organizational chart of cost-account managers.*

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-NSF support for operations in FY 2017. The NSO Program in FY 2017 was developed based on receiving $6,000K of NSF funding for the regular base program (which represents a reduction of $1000K with respect to the previous year), and an additional $11,500K as a funding wedge for ramping up DKIST operations. Thus, the FY 2017 base funding for NSO totals $17,500K. A portion of the DKIST operations funding wedge is utilized to cover the cost of the Headquarters relocation to Boulder, as described in the Cooperative Agreement proposal. This portion is detailed below. The additional $2,500K received in FY 2016 for the ROB in Maui is a one-time increment to facilitate the timely construction of this critical operations facility in Pukalani. This one-time contribution is part of the DKIST Operations carry forward (see below) and it is budgeted exclusively for the ROB construction payments.

NSO receives additional operational support from other sources. In FY 2016, NSO received the first NOAA Space Weather Prediction Center contribution of $800K, intended for support of routine GONG network operations. This funding has allowed the Program to resume and secure the yearly preventive maintenance trips to the six network sites. Upon completion of the interagency agreement between NOAA and the NSF, it is expected that this contribution will continue in FY 2017. NSO also earns revenues from the Sac Peak cafeteria, Visitors Center, and housing operations that are used to support the respective site functions. Except for the cafeteria, these revenues are not expected to diminish considerably in spite of the reduced presence at the site.

In addition to these funds, NSO receives support 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 enhance capabilities needed for these programs. These enhanced capabilities are generally made available to the user community. The FY 2017 budget includes an estimated $600K from grants associated with various activities within NISP.

Table 9.1-1 NSO FY 2017 Funding

(Dollars in Thousands)

NSF Astronomy Division Funding	$17,500
NISP Grants (VSO, NASA Infrastructure, etc.)	$600
NOAA Support	$800
Sunspot Revenue (Housing, Kitchen, VC)	$160
McMP NASA GSFC Support	$55
HQ Office Space	$138
Total NSO Funding	**$19,253**

The external support for the McMath-Pierce Solar Telescope facility (McMP) in FY 2017 totals $55K and originates from the telescope users' pool. No other funding sources have been identified for the McMath. NSO plans to operate the facility by prioritizing telescope time allocation to the external partners that have provided financial support in the recent past, or that will request observing time and secure additional support.

In collaboration with AURA Central Administrative Services (CAS), NSO continues to develop a new budget process aimed at meeting the requirements expressed in the Cooperative Agreement, CSA 1400450. This tool, WEBUD, details the budgetary expenditure information associated with the work packages that NSO develops in the corresponding fiscal year. The budgeting tool allows for the inclusion of Basis of Estimates (BOE) to document the various costs. The WEBUD portal can be accessed online with the appropriate login credentials. The FY 2016 version of WEBUD included base funding and carry forward exclusively. For FY 2017, WEBUD has been extended to include the additional grants funding detailed in Table 9.1-1, which provides a more complete picture of the Observatory funding.

As part of the restructuring of business processes at NSO, and in preparation for the DKIST operations, a new account-numbering system was created in FY 2016. The new account structure eliminates old accounts related to services that have been discontinued and provides a level of consistency amongst NSO's programs. The new account structure will make the reporting process more efficient. The account system uses a nine-digit number that identifies the Observatory (within AURA), the Program (DKIST, NISP, etc.), the funding source (NSF, others), and the work packages with various levels of detail. Both WEBUD and the AURA CASNET accounting tools already incorporate this new account system. As part of the restructuring process, the Business Office has also created a mapping between the new and the old accounts. The FY 2017 budget will be considered final after submission of this Program Plan and will be uploaded from WEBUD into CASNET. Changes to the budget will be made following a change control process. As part of the new business practices at NSO, we are developing a change control process that will be implemented in FY 2017 for changes to the budget presented in this report. The change process follows a model similar to that used by the DKIST construction project.

For FY 2017, the NSO budget process also includes two significant changes: the distribution of indirect costs and the payments for office and lab space. Both changes are included in the spending plan presented here and have been implemented in WEBUD. They originate naturally from the new organization of the Observatory in three well-defined programs: the Director's Office, the DKIST Program, and NISP. In the past, the indirect payments were folded into the Observatory-wide budget line "AURA Business Support". In FY 2017, to reflect the costs of the respective programs, the spending plan presented here explicitly indicates the indirect payments incurred by each program. The second change is the distribution of costs of the facilities among the programs. In FY 2017, the NSO expenditure plan still includes facilities cost at all four NSO sites, but starting in FY 2018, facilities will be restricted to HQ space on the third floor of the SPSC building in Boulder and the ROB in Maui. The ROB will be funded entirely by the DKIST Program. For the space at Headquarters this year, we have implemented a new accounting structure that allocates the cost of office, cubicle, lab space, and a share of the conference rooms to each of the programs. The Director's Office covers the costs of common spaces (hallways, break areas, etc.). The DKIST Construction Project's share of the office space totals $138K in FY 2017.

Table 9.1-2 NSO Spending Plan

Division	Sub-Division	Name	Locked	FTE	Spend Plan	NSF Base Funding	Other Revenue	CarryOver	Variance	Owner	
NSO	NSO HQ	NSO Headquarters	No	11.0	$4,868,327	$2,494,000	$0	$2,373,819	($508)	Pillet, Valentin J	Pkgs | People
NSO	DKIST OP	DKIST Operations	No	32.7	$20,134,253	$10,794,000	$0	$9,340,018	($235)	Rimmele, Thomas R	Pkgs | People
NSO	NSO TUC	NSO Tucson	No	2.1	$574,307	$563,000	$0	$11,309	$2	Piano, Priscilla	Pkgs | People
NSO	NSO NISP	NSO NISP	No	17.0	$3,578,424	$2,198,000	$0	$1,361,451	($18,973)	Hill, Frank	Pkgs | People
NSO	NSO SP	NSO SP	Yes	13.3	$1,824,213	$1,451,000	$153,263	$225,138	$5,188	Hunter, Rex G	Pkgs | People
NSO	AURA BS	AURA Business Support	No	0.0	$0	$0	$0	$0	$0	Hunter, Rex G	Pkgs | People
		Total:		76.0	$30,979,524	$17,500,000	$153,263	$13,311,735	-14,526		

Table 9.1-2 shows the five program areas in which the funds are distributed: NSO Headquarters, DKIST Operations Program, NISP, Sunspot Operations (NSO SP), and Tucson Operations (including McMath-Pierce). As mentioned above, the programs now include the indirect-cost payments instead of consolidating them in the AURA Business Support entry. The fifth column shows the FTEs in each of the programs. Column six details the expenditure target for each program's spending plan. This amount is the sum of the corresponding year's funding from the NSF (column 7), other revenues (column 8), and the program carry forward (column 9). Note that grant funding is not included in this Table. The assignments in column 7 follow the original budget presented in the CA proposal. Column 10 indicates the difference between the spending plan and the available budget.

Table 9.1-3 NSO Budget by Expense Categories

Division	Sub-Division	Description	FTE	Payroll	Services	Supplies	Domestic Travel	Foreign Travel	Sub-Awards	Capital	Indirects	Spend Plan	Ratio	Other Revenue	Carry Over	Variance	NSF	Grants
NSO	NSO HQ	NSO Headquarters	11.0	$1,533,638	$2,484,966	$111,328	$349,083	$67,210	$0	$62,325	$259,777	$4,868,327	14.9%	$0	$2,373,819	($508)	$2,494,000.00	$0.00
NSO	DKIST OP	DKIST Operations	32.7	$4,138,496	$817,878	$209,065	$294,914	$136,987	$0	$13,842,313	$694,601	$20,134,253	61.8%	$0	$9,340,018	($235)	$10,794,000.00	$0.00
NSO	NSO TUC	NSO Tucson	2.1	$316,100	$194,697	$21,500	$8,366	$0	$0	$0	$33,644	$574,307	1.8%	$0	$11,309	$2	$563,000.00	$0.00
NSO	NSO NISP	NSO NISP	25.8	$2,904,928	$686,831	$180,357	$94,286	$136,586	$0	$945,603	$228,469	$5,177,060	15.9%	$0	$1,361,451	$7,376	$2,198,000.00	$1,624,985.00
NSO	NSO SP	NSO SP	13.3	$1,083,566	$411,886	$178,701	$39,026	$0	$0	$0	$111,032	$1,824,213	5.6%	$153,263	$225,138	$5,188	$1,451,000.00	$0.00
NSO	AURA BS	AURA Business Support	0.0	$0	$0	$0	$0	$0	$0	$0	$0	$0	%	$0	$0	$0	$0.00	$0.00
		Total:	84.77	$9,976,728	$4,596,258	$700,951	$785,676	$340,783	$0	$14,850,240	$1,327,524	$32,578,160		$153,263	$13,311,735	$11,822	$17,500,000.00	$1,624,985.00
		Ratio:		31 %	14 %	2 %	2 %	1 %	0 %	46 %	4 %	100 %		0 %	41 %	0 %	54 %	5 %

Table 9.1-3 discloses the budget by program and expense categories as described in the NSF Grant Proposal Guide. The share of the payroll contribution to the Observatory's budget is only 31%. This fraction has historically been much higher, around 80%. In FY 2017, the historic low payroll fraction originates from the significant portion allocated to the ROB payments (*Capital* column). In the stationary phase of DKIST Operations—starting in 2020—we expect this fraction to move to the 50-60% range. The *Services* column represents payments made to a third party that differs for each specific case. Equipment costing < $5K appears in the *Supplies* column and equipment > $5K are in the *Capital* column. Domestic and Foreign travel are provided in columns 8 and 9 and total 3% of the Observatory's budget. The last column discloses grant funding available at the Observatory. While minor grants have existed in other programs, in FY 2017 only NISP benefits from large external contributions from NASA and NOAA. These grant funds have been added to the Program's spending plan in this table, but are not included in Table 9.1-2. With the addition of these external funds, NISP represents 16% of the total Observatory budget, while DKIST is at 62%.

Column 12 shows the indirect costs incurred by each program. These funds are transferred to AURA for the Corporate Office facilities and administrative (F&A) indirect cost, Human Resources, and Central Administrative Services for property management, procurement, and contract administration.

9.2 Work Package Breakout

The online WEBUD tool allows various modes of visualizing the budget distributions and BOE used in each of the programs and NSO's sites. In this section, we present an overview of the most significant expenses projected for each. Tables 9.2-1 through 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 (NSO HQ)

Table 9.2-1 presents the Director's Office budget. Staff included in the Director's Office budget are the Director, the newly created NSO Director's Office Administrator position, the NSO Business Manager, a combination of several fractional FTEs from various administrative positions, a similar combination of fractions of IT personnel, and two EPO personnel. Non-payroll expenses account for travel (including AURA oversight committees), supplies and materials, and other miscellaneous costs incurred by the Director.

Table 9.2-1 Director's Office Budget

Package Group / Package	FTE	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	NSF Base Revenue
NSO HQ	11.0	$1,533,638	$3,334,689	$4,868,327	$0	$4,868,327
Directors Office	3.3	$674,639	$143,960	$818,599		$818,599
AURA Committees			$93,241	$93,241		$93,241
Business/Administration	0.8	$70,868	$107,364	$178,232		$178,232
Recruit/Relo - New Positions			$229,214	$229,214		$229,214
Recruit/Relo - Existing Positions			$57,697	$57,697		$57,697
Carryforward	4.3	$450,080	$1,361,733	$1,811,813		$1,811,813
Insurance			$69,129	$69,129		$69,129
CU Recharge Fees			$48,709	$48,709		$48,709
Science Staff - Research			$0	$0		$0
Research Assistants			$0	$0		$0
NSO Science-Collaborations			$0	$0		$0
NISP Operations Service			$0	$0		$0
DKIST Operations Service			$0	$0		$0
CSP Activities			$0	$0		$0
EPO - Scientists			$0	$0		$0
Joint CU/NSO			$0	$0		$0
Hale Post Doc			$0	$0		$0
HQ Operations			$489,282	$489,282		$489,282
Boulder Computing IT	0.5	$86,525	$82,847	$169,372		$169,372
Vehicles			$0	$0		$0
HQ Development & Relocation			$608,111	$608,111		$608,111
Instrument Development			$0	$0		$0
Education and Public Outreach	2.0	$251,526	$43,403	$294,929		$294,929
Total:	**11.0**	**$1,533,638**	**$3,334,689**	**$4,868,327**	**$0**	**$4,868,327**
Target:						**$2,494,000**
Variance:						**($2,374,327)**

A significant fraction of the Director's Office budget corresponds to the carry forward from FY 2016 ($1.7M). WEBUD contains the details of the re-budgeting of these funds, including the BOE. Here we list the most significant items covered by this budget:

1. The Critical Science Plan Workshops described in Section 5.4. A total budget of $150K is allocated to workshop organization. Additionaly, $67K has been budgeted for NSO staff travel to the workshops and related activities. Note that since the CSP workshop activities are funded by the carry forward, the corresponding entry on Table 9.2-1 has no budget allocated.
2. Start-up package for the second shared faculty position with CU-Boulder. Including the search committee expenses and selected candidate moving costs, the total amount is $210K.
3. Equipment moves to Boulder and Maui that have not occurred yet because of the delays with the ROB. The transition budget carries $100K for transporting equipment to the island.
4. New website redesigns estimated at $100K.
5. Remodeling of the 3rd floor to accommodate new offices, $75K (per CU quote)
6. Payroll support (senior scientists, EPO support), $450K.
7. The EPO start-up package ($110K) due to the delays in the hirings.

The HQ lease this year is distributed among the programs. Payment from the Director's Office (HQ Operations line) corresponds to the space used by the Director's Office itself, and shared spaces. The HQ Development budget line includes the cost in 2017 of relocating the Sunspot and Tucson staff to Boulder, the estimated vacation accrual and other benefits for employees impacted by the transition, and the transport of equipment to Boulder and Maui.

The IT Support line in Boulder covers the infrastructure needed to host the new VPN service, Web servers and a consolidated e-mail system for NSO. Plans for a minimal scientific support infrastructure required during the transition are also included in the IT budget. After the transition, this IT infrastructure will be dedicated to visitors and students.

NSO started an EPO Program under the Director's Office in FY 2016 by hiring the Head of Education and Public Outreach. This person leads outreach activities of the Observatory and will have one assistant in Maui. The EPO Assistant position has been recently advertised and is expected to be filled in early January 2017. The EPO Assistant will focus on promoting solar physics within the local community, in particular with K-12 students and teachers on the island. The late hire of these positions has provided some carry forward funds that are being re-budgeted as a start-up package for the EPO Program. The use of these funds will be beneficial toward increasing the visibility of NSO in general, and of DKIST in particular, during the 2017 total solar eclipse. The EPO budget in FY 2017 totals $410K including the start-up funds.

The funding wedge for DKIST operations in FY 2017 is $11.5M, a fraction of which is being used to cover the Headquarters relocation and expenses. In FY 2015, this fraction was 40% of the funding wedge. In FY 2016, this fraction was reduced to 30%. With no large furniture costs for the 3rd floor in FY 2017, and with the increase in the DKIST funding wedge, we estimate that HQ development uses only 7% of the wedge. Although not directly used for the DKIST ramp up, we note that DKIST operations benefit from basically all of the budget items included in the Director's Office (relocations, IT support, etc.).

9.2.2 DKIST Operations Program

The DKIST Operations Program is under the direction of Thomas Rimmele as DKIST Associate Director. In FY 2017, the DKIST Operations Program will also become the largest program with FTEs, surpassing NISP. Table 9.2-2 presents the budget for FY 2017 divided into work packages. The DKIST scientific staff corresponds to existing personnel transferred from NSO programs in Sunspot and Tucson, and new hires expected this year. Two scientists are already based in Maui, where they interact with our instrument partners on the island.

All aspects of operations are being ramped up this year in both Boulder and Maui. The Boulder-based Data Center continues with additional personnel hires. This year, the Data Center team will concentrate on conducting a series of reviews, and only after the reviews are successfully completed will the acquisition of equipment begin (expected in FY 2018).

The IT team in Boulder for the DKIST Program ramps up with almost 2 FTEs to design the scientific support infrastructure. Two work packages that increase significantly in FY 2017 are the Operations Development and the Instrumentation Program, including the next generation of instruments and MCAO. For operations, we have hired two observers who are undergoing training at the DST in Sunspot. An additional observer position will be available in FY 2017.

A significant effort is planned for construction of the Remote Office Building in Pukalani. The ROB has successfully passed an Environmental Assessment study in FY 2016. The AURA Board has approved the Observatory's selection of the building contractor, and we are in the final phases of obtaining the construction permits on the island. Starting construction of the ROB is the most important priority for the Observatory in FY 2017 as it is the factor that's holding back the build-up of the operations workforce on the island. In the budget presented here, DKIST is assigning $8,400K for payments to the selected contractor. The ROB construction budget is in the carry forward entry.

Table 9.2-2 DKIST Operations Program Budget

Package Group / Package	FTE	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	NSF Base Revenue
DKIST Operations	32.7	$4,138,496	$15,995,757	$20,134,253	$0	$20,134,253
Operations Management			$0	$0		$0
Directorate	0.2	$56,466	$36,083	$92,549		$92,549
Business/Administration	0.3	$16,637	$1,191	$17,828		$17,828
Quality Control			$39,167	$39,167		$39,167
Carryforward			$9,210,655	$9,210,655		$9,210,655
DKIST Science			$0	$0		$0
DKIST Science Staff - Research	6.8	$765,046	$340,015	$1,105,061		$1,105,061
Science - Operations Support Staff	3.3	$421,299	$171,785	$593,085		$593,085
Science - DKIST Maui Operations Service			$0	$0		$0
Science - DKIST Data Center Service			$0	$0		$0
Science- DKIST EPO	0.2	$31,212	$2,235	$33,447		$33,447
Science - Development (New Programs)			$0	$0		$0
Science- FL Data Center Development	0.8	$139,902	$33,621	$173,523		$173,523
Science - FL Ops Tools Development	0.6	$79,603	$5,700	$85,302		$85,302
Science - MCAO development	1.3	$119,344	$8,545	$127,889		$127,889
Science - Next Generation Instruments			$0	$0		$0
Science - Data Center enhancements	0.8	$95,618	$20,484	$116,102		$116,102
Facilities			$0	$0		$0
Facilities Maui			$0	$0		$0
DKIST Facility			$0	$0		$0
DKIST Facility Engineering			$0	$0		$0
ROB Facility			$0	$0		$0
ROB Engineering			$0	$0		$0
Facilities Boulder			$0	$0		$0
HQ expenses			$133,110	$133,110		$133,110
HQ Engineering			$0	$0		$0
Boulder Computing - IT	1.5	$203,104	$207,124	$410,229		$410,229
Data Center Ops			$0	$0		$0
Development (New Programs)			$0	$0		$0
First Light Data Center Development	6.2	$955,108	$893,332	$1,848,440		$1,848,440
Operations Development	0.2	$27,197	$288,215	$315,412		$315,412
FL Operations Tools Development	0.7	$132,810	$109,168	$241,977		$241,977
Operator Training	2.0	$180,737	$49,901	$230,638		$230,638
MCAO development	3.8	$357,192	$551,219	$908,411		$908,411
Next Generation Instruments	2.3	$285,523	$2,981,657	$3,267,180		$3,267,180
Data Center Enhancements	1.0	$83,150	$99,318	$182,467		$182,467
Ops Tools Enhancements			$36,716	$36,716		$36,716
Remote Office Building - development	1.0	$188,549	$776,517	$965,067		$965,067
Total:	32.7	$4,138,496	$15,995,757	$20,134,253	$0	$20,134,253
Target:						$10,794,000
Variance:						($9,340,253)

9.2.3 NSO Integrated Synoptic Program

The NISP combines staff from SOLIS and GONG under Frank Hill as Associate Director. Following the recommendation of the Portfolio Review Committee, the NSF base funding for NISP in FY 2017 continues to be $2M (excluding indirect payments). The total budget is augmented by the NOAA contribution of $800K and by $600K of grants (see below) as described in Section 6.3. The $2.5M for GONG refurbishment minus the expenses incurred in FY 2016 is part of the Program's carry forward.

The NISP budget breakdown is presented in Table 9.2-3. Currently, NISP has a total of 25 FTEs. The NSF base funding, including the GONG refurbishment activity, covers 17 FTEs. The NOAA funds support 3.2 FTEs, and the grants an additional 5.2 FTEs. The soft money support for the Program is important, but it only represents 20% of the workforce. NISP plans to open two two-year engineering positions to cover aspects of the GONG refurbishment project.

Table 9.2-3 NSO Integrated Synoptic Program Budget

Package Group / Package	FTE	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	NSF Base Revenue
NSO NISP	17.0	$1,978,075	$1,600,349	$3,578,424	$0	$3,578,424
Scientific Staff	6.6	$896,731	$161,628	$1,058,358		$1,058,358
Data Center	5.1	$564,898	$234,575	$799,473		$799,473
Instru Devel and Maint	0.3	$42,216	$3,023	$45,238		$45,238
SOLIS Relocation			$154,103	$154,103		$154,103
Admin	0.8	$73,214	$74,824	$148,037		$148,037
GONG Refurbishment	4.3	$401,017	$972,197	$1,373,214		$1,373,214
Total:	17.0	$1,978,075	$1,600,349	$3,578,424	$0	$3,578,424
Target:						$2,198,000
Variance:						($1,380,424)

NISP comprises an Atmospheric Section and an Interior Section, each led by a program scientist who reports to the NISP Associate Director. The Telescope Operations and Instrument Development staff, supervised by the NISP Head of Engineering, support both SOLIS and GONG instruments and upgrades as required. The budget includes $154K for SOLIS relocation. This number needs further consolidation, pending the selection of the final site. The scientific staff support the various NISP data products and respond to the community's need for new data. Both SOLIS and GONG data are reduced daily and added to the NSO Digital Library for downloading by the solar community.

The main activities included in the GONG refurbishment budget remain unchanged:

- Improved stability in the zeropoint of GONG magnetograms (new liquid crystal modulators).
- New cameras.
- Upgraded H-alpha filters to acquire Doppler shifts.
- Data Center upgrades to cope with new data products (H-alpha Doppler shifts).
- Improved HVAC in shelters.
- Field trips to the six GONG sites

The BOE for the non-payroll portion of this budget was uploaded to the FY 2016 WEBUD budget. We have estimated a total of 7 FTEs (319 man-weeks) dedicated to this activity over a period of one year. Given the transition in which NISP is immersed, however, we are distributing the effort over a period of three years with 0.3 FTEs already dedicated in FY 2016, 4.2 FTEs in FY 2017 and 2.5 FTEs in FY 2018. Most of the hardware acquisitions will occur in FY 2017. We note that as a result of this upgrade, operations of the network might be slightly more expensive than in the past, as some of the GONG sites' bandwidth will need to be increased to accommodate the new data products.

Table 9.2-3b discloses the distribution of the NOAA SWPC funds that cover payroll for the maintenance of the network sites and the cost of the operations, including the preventive maintenance trips. The table also details the various scientific and infrastructure grants obtained by the program.

Table 9.2-3.b NISP Budget with External Funds

Package Group / Package	FTE	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	Grants Base Revenue
NSO NISP	8.8	$926,853	$671,783	$1,598,636	$0	$1,598,636
SWPC Payroll	3.2	$365,118	$4,647	$369,765		$369,765
SWPC Learmonth (LE)			$23,845	$23,845		$23,845
SWPC Udaipur (UD)			$26,544	$26,544		$26,544
SWPC Tenerife (TD)			$28,769	$28,769		$28,769
SWPC CTIO (CT)			$11,693	$11,693		$11,693
SWPC Big Bear (BB)			$54,860	$54,860		$54,860
SWPC Mauna Loa (ML)			$64,717	$64,717		$64,717
SWPC Tucson			$58,169	$58,169		$58,169
SWPC Network			$4,120	$4,120		$4,120
SWPC GONG Relocation			$197,259	$197,259		$197,259
NASA Infrastructure	2.7	$274,411	$90,692	$365,103		$365,103
VSO	0.5	$57,941	$103,547	$161,488		$161,488
NWRA Farside	0.3	$23,919	$304	$24,224		$24,224
Georgia State Dynamo	0.5	$46,536	$592	$47,129		$47,129
Pevtsov No.1	0.9	$87,285	$1,111	$88,396		$88,396
Pevtsov No. 2			$0	$0		$0
Pevtsov No. 3	0.6	$56,490	$719	$57,209		$57,209
Pevtsov No. 4	0.2	$15,153	$193	$15,346		$15,346
Total:	8.8	$926,853	$671,783	$1,598,636	$0	$1,598,636
Target:						$1,624,985
Variance:						$26,349

9.2.4 Tucson/McMath-Pierce

Table 9.2-4 shows the budget breakdown for Tucson and the support for the McMath-Pierce Solar Telescope (McMP) facility. As in FY 2016, the full FTE of the Tucson site leader is included in this budget. The McMP uses 0.2 FTE of a scientist that is shared with DKIST (0.8 FTE).

Table 9.2-4 NSO Tucson/McMath-Pierce Budget

Package Group / Package	FTE	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	NSF Base Revenue
NSO Tucson	2.1	$316,100	$258,207	$574,307	$0	$574,307
Scientific Staff	1.2	$232,241	$29,077	$261,318		$261,318
Telescope Ops	0.3	$18,693	$11,829	$30,521		$30,521
Admin	0.6	$65,166	$13,058	$78,224		$78,224
Kitt Peak Support			$50,136	$50,136		$50,136
NOAO Facilities Use Fee			$154,107	$154,107		$154,107
Total:	2.1	$316,100	$258,207	$574,307	$0	$574,307
Target:						$563,000
Variance:						($11,307)

The Tucson/McMP staff provides support for operations of the McMath-Pierce Solar Telescope. This year, the effort level of McMP observing support has been reduced to 0.25 FTE. This reduction follows the guidelines in the letter from the NSF/AST Division Director to the McMP Consortium (dated May 31, 2013).

NSO has informed NOAO that we will discontinue using the motor pool service, thus reducing the McMath Joint Use Fee for Kitt Peak to $48K, about half of the FY 2016 amount. Unfortunately, the consortium has not made substantial progress in establishing the administrative structure needed to run the facility. In spite of a number of attempts, no backbone institutional support has been identified so far. However, continued interest by several users exists, enabling limited McMP operations in FY

2017. Contributions from various groups at NASA/GSFC provide external funding that amounts to $55K, which helps to continue operating the telescope for a significant fraction of the year.

In FY 2017, NOAO continues to charge a square-foot fee that covers utilities, security, custodial service, and shared infrastructure support including library and Internet services. The total contribution that NSO provides NOAO for these services in FY 2017 is $154K.

9.2.5 Sacramento Peak

In FY 2017, Sacramento Peak has seven fewer FTEs than the previous year. This reduction originates from the transfer of personnel to Headquarters in Boulder and staff attrition. This year, the budget for Sac Peak is significantly below the historic $2M figure, consistent with the reductions in personnel and a reduced number of facilities in use. The budget breakdown is presented in Table 9.2-5.

Table 9.2-5 NSO/Sacramento Peak Budget

Package Group / Package	FTE	Staff Cost	Non-Staff Cost	Spend Plan	Other Revenue	NSF Base Revenue
NSO SP	13.3	$1,083,566	$740,646	$1,824,213	$153,263	$1,670,950
Administrative Services	1.8	$124,459	$19,272	$143,731		$143,731
Scientific Staff	1.0	$156,260	$19,186	$175,446		$175,446
Telescope Operations	2.0	$181,472	$38,725	$220,196		$220,196
Instrument Development and Telescope Maintenance	3.0	$335,473	$65,620	$401,093		$401,093
Computing Support	0.4	$38,999	$70,424	$109,423		$109,423
Facility Maintenance	2.2	$133,719	$264,525	$398,244		$398,244
Housing	1.0	$45,776	$37,504	$83,280	$98,831	($15,551)
Kitchen	0.9	$25,652	$9,447	$35,098	$6,695	$28,403
Visitor Center	1.1	$41,758	$32,097	$73,855	$47,737	$26,118
Sac Peak Carryforward			$183,847	$183,847		$183,847
Total:	13.3	$1,083,566	$740,646	$1,824,213	$153,263	$1,670,950
Target:						$1,451,000
Variance:						($219,950)

NSO/SP scientific staff support for the Dunn Solar Telescope in FY 2017 will be Boulder-based to accommodate DKIST operations-definition activities. These scientists will travel to the DST on an as needed basis, largely when visiting scientists at the telescope need support. 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 DST Program Scientist also chairs the TAC process and observatory operations.

The Instrument Development and Telescope Maintenance staff support DST operations and upgrades to the DST control systems, and focal-plane instrumentation so users can take full advantage of diffraction-limited imaging. No reduction in DST technical support FTE allocations will occur in FY 2017. However, the telescope still operates with only two FTEs (out of a pool of three observers that are shared with DKIST), forcing the telescope to be offered only during the weekdays.

The Sac Peak administrative staff oversees 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. The Sacramento Peak carry forward is primarily dedicated to site maintenance and transition activities.

9.2.6 AURA Fees and NOAO Support

Table 9.2-6 shows the expenses NSO incurs for AURA Facilities and Administrative (F&A) costs, Central Administrative Services (CAS), and Human Resources (HR). Table 9.1-3 discloses these costs by program, but it also includes an additional $22K of indirect costs incurred by the NISP grants.

Table 9.2-6 AURA Fees

Indirect Cost Type	Charge
AURA CAS Support	$589,758
AURA HR Support	$200,676
AURA Corporate F&A	$514,389
Total	$1,304,823

AURA HR has stationed permanently one person at NSO HQ in Boulder and AURA CAS is funding 50% FTE of a buyer also located in Boulder. The AURA Management Fee is currently being negotiated with the NSF and is not included here.

9.3 FY 2016 Budget Reconciliation

Table 9.3 is the final reconciliation of the NSO FY 2016 budget, which shows expenditures, encumbrances, adjustments, and estimated final balance by Division. A new column that provides the savings in indirect costs in each of the programs is included in this Table and reflects the new way that indirect costs in FY 2017 are budgeted by NSO, as explained in Section 9.1.

Table 9.3 Summary FY 2016 Preliminary Budget Reconciliation

Division	Budget	Expenditures	Encumbrances	Prior Year Encumbrances	Balance	Indirect Savings	Estimated Final Balance
Director's	$ 4,957,491.00	$ 2,476,980.28	$ 523,782.94	$ 218,314.00	$ 2,175,041.78	$ 198,778.11	$ 2,373,819.90
DKIST Ops	$ 8,648,225.00	$ 2,333,939.89	$ 118,457.67	$ 370,719.00	$ 6,566,546.44	$ 273,472.18	$ 6,840,018.62
NISP	$ 4,750,638.00	$ 3,409,540.91	$ 337,970.68	$ 299,354.00	$ 1,302,480.41	$ 58,970.98	$ 1,361,451.39
Sac Peak	$ 2,181,910.00	$ 1,978,684.40	$ 80,368.61	$ 94,775.00	$ 217,631.99	$ 7,506.59	$ 225,138.58
Tucson	$ 405,000.00	$ 389,843.13	$ 4,604.07	$ 500.00	$ 11,052.80	$ 256.24	$ 11,309.04,.
AURA/NOAO	$ 1,224,376.00	$ 685,334.83	$ 3,885.06	$ 3,828.00	$ 538,984.11	$ 0.0	N/A
TOTAL	**$ 22,167,640.00**	**$ 11,274,323.44**	**$ 1,069,069.03**	**$ 987,490.00**	**$10,811,737.53**	**$ 456,057.36**	**$ 10,811,737.53**

The significant amount of unspent budget is due to the accumulation, now over two years, of funds allocated for the ROB and the impacts of its delay. The DKIST Program used in FY 2016 only 26% of its original budget while waiting for the uncertainties created by the ROB and its final cost to be resolved. The DKIST Program also carries forward additional funds that result from the inability to implement the hires as described in the CA in the absence of a place to accommodate the personnel. This delay has created a total carry forward of almost $7M to which we must add the one-time contribution for the ROB of $2.5M received in FY 2016 (this amount is not added to Table 9.3 but it is included in Table 9.1-2). The funds carried forward in the Director's Office are similar to the amount in previous years. For NISP, $1.35M is the balance of GONG refurbishment funds.

APPENDICES

This page intentionally left blank.

APPENDIX A. NATIONAL SOLAR OBSERVATORY 2020–2025 VISION[1]

NSO will support and lead community research into the nature of the Sun by providing critical ground-based 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 Physics.* The NSO science vision is focused on the basic question[1] 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 effects[2]. 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 atmosphere[4];
2. Study the drivers and manifestations of the long-term, quasi-cyclic, inhomogeneous and intermittent solar magnetic fields and flows;

[1]See NSO 2012-2016 Long Range Plan for science goals (*http://www.nso.edu/reports*)
[2]NWNH, p. 64
[3] NWHH, pp. 29, 37,38, 60,61, 115
[4] NWHH, p. 64

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 today[5], 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 will[6]:

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, 2015 – September 30, 2016)

In the 12 months ended 30 September 2016, 32 observing programs, which included 3 thesis programs, were carried out at NSO. Associated with these programs were 54 scientists, students and technical staff from 25 US and foreign institutions.

NSO Observing Programs by Type (US and Foreign)		
12 Months Ended September 2016	*Nbr*	*% Total*
Programs (US)	24	75%
Programs (non-US)	5	16%
Thesis (US, involving 1 grad students)	1	3%
Thesis (non-US, involving 2 grad students)	2	6%
Total Number of Unique Science Projects*	**32**	**100%**

**Includes observing programs conducted by AURA staff scientists.*

Users of NSO Facilities by Category	Visitors				AURA Staff
	US	*Non-US*	*Total*	*% Total*	
PhDs	27	19	46	85%	13
Graduate Students	2	2	4	7%	0
Undergraduate Students	3	0	3	6%	0
Other	1	0	1	2%	15
Total Users	**33**	**21**	**54**	**100%**	**28**

Institutions Represented by Visiting Users**	***US***	***Non-US***	***Total***	***% Total***
Academic	11	8	19	76%
Non-Academic	4	2	6	24%
Total Academic & Non-Academic	**15**	**10**	**25**	**100%**

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

Number of Users by Nationality			
Brazil	1	Italy	5
France	2	Japan	1
Germany	5	Spain	4
Ireland, UK	3	United States	61

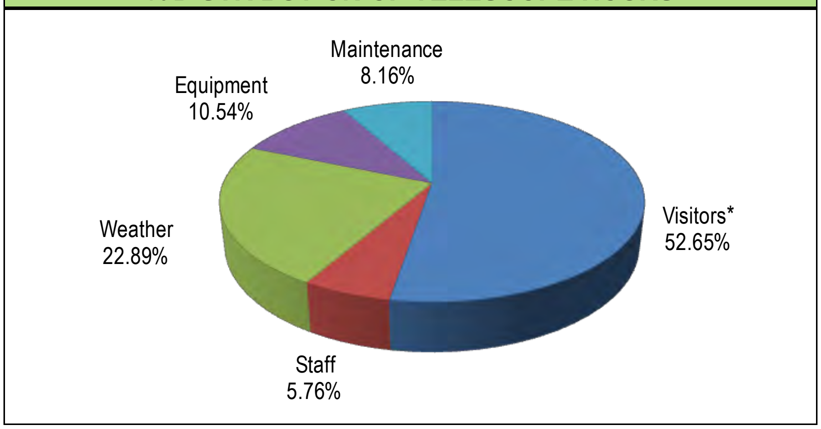
Institutions Represented by Users
Foreign Institutions (10)
Universidade Presbiteriana Mackenzie, Sao Paolo
Leibniz Institute for Astrophysics, Potsdam
University of Koeln
Northumbria University
Queen's University
University of Rome "Tor Vergata"
University of Tokyo, Dept. of Astronomy, NAOJ
Laboratoire Atmosphères, Milieux, Observations Spatiales
INAF - Osservatorio Astronomico di Roma
Instituto de Astrofisica de Canarias
US Institutions (15)
Boston University
California State University, Northridge
Catholic University
Embry Riddle Aeronautical University, Daytona
Dickinson College
George Mason University
New Mexico State University
Oregon State University
University of Arizona
University of California, Berkeley
Unviesity of Colorado, Boulder
University of Hawaii, IFA
NASA Marshall Space Flight Center
NASA/Goddard Space Flight Center (NASA/GSFC)
Northrup Grumman Corp.

FY 2016 USER STATISTICS – TELESCOPE USAGE & PERFORMANCE DATA

In the fiscal year ended 30 September 2016, 52.7% of the total available telescope hours at NSO/Sacramento Peak, NSO/Kitt Peak, and the SOLIS/GONG "Farm" in Tucson went to the observing programs of visiting principal investigators; 5.8% were devoted to those of NSO scientists. Scheduled maintenance (including instrument tests, engineering, and equipment changes) accounted for 8.2% of total allotted telescope hours.

Total "downtime" (hours lost to weather and equipment problems) for NSO telescopes was 33.4%. A significant portion of these lost observing hours were due to bad weather (2.9%), with 10.5% lost to equipment problems.

ALL NSO TELESCOPES
% DISTRIBUTION OF TELESCOPE HOURS



NSO TELESCOPES
Percent Distribution of Telescope Hours
(Scheduled vs. Downtime)
01 October 2015 - 30 September 2016

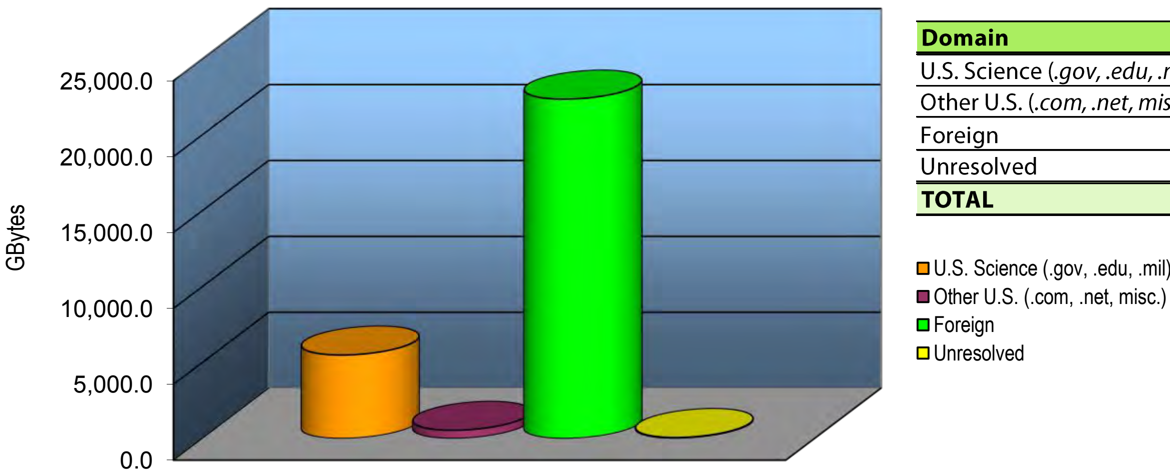
Telescope	Hours Scheduled	% Hours Used By: Visitors[a]	% Hours Used By: Staff	% Hours Lost To: Weather	% Hours Lost To: Equipment	% Hrs. Lost To: Scheduled Maintenance
Dunn Solar Telescope/SP	**2,862.0**	**29.1%**	**6.0%**	**19.3%**	**5.7%**	**40.0%**
McMath-Pierce*	**2,841.0**	**45.4%**	**22.4%**	**29.1%**	**3.1%**	**0.0%**
SOLIS "Farm", Tucson[a,b]	**8,316.3**	**63.2%**	**0.0%**	**22.0%**	**14.8%**	**0.0%**
FTS Lab[c*]	0.0	0.0%	0.0%	0.0%	0.0%	0.0%
Evans Solar Facility	0.0	0.0%	0.0%	0.0%	0.0%	0.0%
Hilltop Dome	0.0	0.0%	0.0%	0.0%	0.0%	0.0%
All Telescopes	**14,019.3**	**52.7%**	**5.8%**	**22.9%**	**10.5%**	**8.2%**

[a]*Includes synoptic programs for which all data are made available immediately to the public and scientific community at large.*
[b]*SOLIS was relocated from Kitt Peak to the University of Arizona agricultural campus (or "Farm") in Tucson.*
[c]*During 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, 2015 - September 30, 2016)

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 2015 - 30 September 2016



Domain	Gbytes
U.S. Science (*.gov, .edu, .mil*)	5,497.5
Other U.S. (*.com, .net, misc.*)	538.7
Foreign	22,355.2
Unresolved	64.7
TOTAL	**28,456.0**

PRODUCT DISTRIBUTION BY DOWNLOADED GBYTES
01 October 2015 - 30 September 2016

Site	Product Type	Gbytes	%
T	NISP/GONG H-alpha	7,820.7	37.5%
SP & T	Other	5,668.7	27.2%
T	NISP/GONG (Magnetograms, spectra, time series, frequencies)	4,044.6	19.4%
T	NISP/GONG Helioseismology	2,669.1	12.8%
T	NISP/SOLIS (VSM, ISS, FDP)	371.3	1.8%
T	FTS (Spectral atlases, general archive)	95.4	0.5%
T	KPVT (magnetograms, synoptic maps, helium images)	85.7	0.4%
SP	Staff Pages	44.8	0.2%
SP	Press Releases	26.7	0.1%
SP	General Information	10.4	0.0%
SP	DST Service Mode Support	4.0	0.0%
SP	SMEI Experiment & Data Pages	0.1	0.0%
T	Evans/SP Spectroheliograms (Hα, Calcium K images)	0.1	0.0%
SP	Icon & Background Images	0.1	0.0%
TOTAL		**20,841.6**	**100.0%**

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 Hα 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)	HAO
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, NorthWest Research Associates
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, Georgia 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.

APPENDIX D. PUBLICATIONS

(OCTOBER 2015 THROUGH SEPTEMBER 2016)

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

The following is a list of known refereed papers, conference proceedings and non-refereed papers published during FY 2016 by NSO staff, REU and RET program participants, graduate students, and non-REU undergraduates, as well as papers resulting from the use of NSO facilities.

Refereed Publications (95)

1. Aschwanden, M. J., **Reardon, K.**, Jess, D. B. 2016, "Tracing the Chromospheric and Coronal Magnetic Field with AIA, IRIS, IBIS, and ROSA Data", ApJ **826** (1), id. 61, 18 pp.

2. Balasubramaniam, K. S. and **Henry, T. W**. 2016, "Numbers from ISOON: A Ten-Year Data Analysis"**,** SoPh **291** (9-10), 3123-3138.

3. **Beck, C.**, Rezaei, R., Puschmann, K. G., Fabbian, D. 2016, "Spectroscopy at the Solar Limb: II. Are Spicules Heated to Coronal Temperatures? SoPh **291** (8), 2281-2328.

4. Berrilli, Francesco, Soffitta, Paolo, Velli, Marco, Sabatini, Paolo, Bigazzi, Alberto, Bellazzini, Ronaldo,…**Pillet, Valentin Martinez**, … 2015, "ADAHELI: exploring the fast, dynamic Sun in the x-ray, optical, and near-infrared", JATIS **1**, id. 044006.

5. **Bertello, L., Pevtsov, A. A.**, Tlatov, A. G., Singh, J. 2016, "Correlation between Sunspot Number and Ca uc(ii) K Emission Index"**,** SoPh **291** (9-10 2967-2979.

6. **Bertello, L., Pevtsov, A. A.**, Tlatov, A. G., and Singh, J. 2016, "Solar Ca II K Observations"**,** AsJPh **25**(3), 295-310.

7. Bolsée, D., Pereira, N., Cuevas, E., García, R. A., Redondas, A. 2016, "Comments to the Article by Thuillier et al. "The Infrared Solar Spectrum Measured by the SOLSPEC Spectrometer Onboard the International Space Station" on the Interpretation of Ground-based Measurements at the Izaña Site"**,** SoPh **291** (8), 2473-2477.

8. Borrero, J. M., A Ramos, A., Collados, M., Schlichenmaier, R., Balthasar, H., Franz, M., Rezaei, R., Kiess, C., D Suárez, O., Pastor, A. …**Schmidt, D.**, et al. 2016, "Deep probing of the photo-spheric sunspot penumbra: no evidence for magnetic field-free gaps", A&A **596** (A2), 14 pp.

9. **Brandenburg, A**., **Petrie, G. J. D.**, Singh, N. K. 2016, "Two-scale analysis of solar magnetic helicity", eprint arXiv:1610.05410, ApJ, 8 pp.

10. Brown, L. R., Nikitin, A. V., Sung, K., Rey, M., Tashkun, S. A., Tyuterev, Vl. G., Crawford, T. J., Smith, M. A. H., Mantz, A. W. 2016, “Measurements and modeling of cold $^{13}CH_4$ spectra in the 3750-4700 cm^{-1} region”, JQSRT **174**, 88-100.

11. Cheung, M. C. M., van Driel-Gesztelyi, L., **Pillet, V. M.**, Thompson, M. J. 2016, "The Life Cycle of Active Region Magnetic Fields", SSRv Online First, 08/2016.

12. Clette, F., Cliver, E. W., Lefèvre, L., Svalgaard, L., Vaquero, J. M., **Leibacher, J. W.** 2016, “Preface to Topical Issue: Recalibration of the Sunspot Number”, SoPh **291** (9-10), 2479-2486.

13. **Cliver, E. W.** 2016, "Comparison of New and Old Sunspot Number Time Series", SoPh 291 (9-10), 2891-2916.

14. **Cliver, E. W.** 2016, "Flare vs. Shock Acceleration of High-energy Protons in Solar Energetic Particle Events", ApJ **832** (2), id. 128, 8 pp.

15. **Cliver, E. W.** and Ling, A. G. 2016, "The Discontinuity Circa 1885 in the Group Sunspot Number", SoPh **291**(9-10) 2763-2784.

16. **Criscuoli, S.** 2016, "Angular Dependence of the Facular–Sunspot Coverage Relation as Derived by MDI Magnetograms", SoPh **291**(7), 1957-1975.

17. de Jager, C., Akasofu, S., Duhau, S., Potgieter, M., **Livingston, W. C.** 2016 Nieuwenhuijzen, H. 2016, "A remarkable recent transition in the solar dynamo", SSRv, in press.

18. Devi, V. M., Benner, D. C., Sung, K., Brown, L. R., Crawford, T. J., Miller, C. E., et al. 2016, “Line parameters including temperature dependences of self- and air-broadened line shapes of $^{12}C^{16}O_2$: 1.6-mum region”, JQSRT **177**, 117-144.

19. **Díaz Alfaro, M.**, Pérez Hernández, F., **González Hernández, I.**, Hartlep, T. 2016, "Seismic Holography of the Solar Interior near the Maximum and Minimum of Solar Activity", SoPh **291** (5), 1323-1340.

20. Efremov, V. I., Parfinenko, L. D., Solov'ev, A. A. 2016, “Ultra Low-Frequency Oscillations of a Solar Filament Observed by the GONG Network”, SoPh **291** (11), 3357-3367.

21. Elsworth, Y., Broomhall, A-M., **Gosain, S.**, Roth, M., Jefferies, S.M., **Hill, F.** 2015, “The Importance of Long-Term Synoptic Observations and Data Sets for Solar Physics and Helioseismology”, SSRv **196** (1-4), 137-166.

22. Falco, M., Borrero, J.. M., Guglielmino, S. L., Romano, P., Zuccarello, F., **Criscuoli, S.**, Ermolli, I., Jafarzadeh, S., and Rouppe van der Voort, L. 2016, "Kinematics and Magnetic Properties of a Light Bridge in a Decaying Sunspot", SoPh **291**(7), 1939-1955.

23. Franz, M., Collados, M., Bethge, C., Schlichenmaier, R., Borrero, J.. M., Schmidt, W., Lagg, A., Solanki, S.K., Berkefeld, T., Kiess, C., …**Schmidt, D.** et al. 2016, "Magnetic fields of opposite polarity in sunspot penumbrae", A&A **596** (A4), 13 pp.

24. **Giampapa, M. S.** 2016, "The Solar-Stellar Connection", AsJPh **25** (3), 411-455.

25. Golovko, A. A., Salakhutdinova, I. I. 2015, “Evolution of solar active regions: Detecting the emergence of new magnetic field through multifractal segmentation”, ARep **59** (8), 776-790.

26. **Gosain, S.** 2016, "Current trends in ground based solar magnetometry", AsJPh **25** (3), 221-232.

27. G**osain, S.**, Filipov, B., Ajor-Maurya, R., 2016, "Interrupted Eruption of Large Quiescent Filament Associated with a Halo CME", ApJ **821**(2).

28. Guglielmino, S. L., Zuccarello, F., Romano, P., Cristaldi, A., Ermolli, I., **Criscuoli, S.**, Falco, M. 2016, "A Multi-instrument Analysis of a C4.1 Flare Occurring in a δ Sunspot", AJ **819**(2), id.157, 17 pp.

29. Harra, L., Baker, D., Howe, R., **Leibacher, J.**, van Driel-Gesztelyi, L. 2015, “Preface: Probing the Sun Inside and Out,” SoPh **290** (11), 3091-3094.

30. Hawley, S. L., Angus, R., Buzasi, D., Davenport, J. R. A., **Giampapa, M.,** Kashyap, V., Meibom, S. 2016 “Maximizing Science in the Era of LSST, Stars Study Group Report: Rotation and Magnetic Activity in the Galactic Field Population and in Open Star Clusters”, arXiv:1607.04302, 23 pp.

31. Hayashi, K., Yang, S., Deng, Y. 2016, “Comparison of potential field solutions for Carrington Rotation 2144”, JGRA **121**, (2), 1046-1061.

32. Howe, R. 2016, "Should We Try to Re-Construct the American Relative Sunspot Index (Ra)?”, AAVSO **44**(1).

33. Howe, R. 2016 "Solar interior structure and dynamics", AsJPh **25** (3), 221-232.

34. Howell, S. B., Ciardi, D. R., **Giampapa, M. S.**, Everett, M. E., Silva, D. R., Szkody, P. 2016, "Variability of Kepler Solar-like Stars Harboring Small Exoplanets", AJ **151** (2), 43.

35. **Jaeggli, S. A.** 2016, "Multi-wavelength Study of a Delta-spot I: A Region of Very Strong, Horizontal Magnetic Field", ApJ **818** (1), id.81, 12 pp.

36. **Jaeggli, S. A.**, Norton, A. A. 2016, “The Magnetic Classification of Solar Active Regions 1992-2015”, ApJL **820** (1), id. L11, 4 pp.

37. **Jain, K.**, and **Komm, R. W.** 2016, "Solar origins of space weather", AsJPh **25** (3).

38. **Jain, K.**, **Tripathy, S. C.**, Ravindra, B., **Komm, R. W.**, **Hill, F.** 2016, "Horizontal Flows in Active Regions from Ring-diagram and Local Correlation Tracking Methods", ApJ **816** (1), id.5.

39. Javaraiah, J., **Bertello, L.** 2016, "Short-Term Variations in the Equatorial Rotation Rate of Sunspot Groups", SoPh **291** (12), 3485-3500.

40. Jin, M., Manchester, W. B., van der Holst, B., Sokolov, I., Toth, G., Mullinix, R. E., Taktakishvili, A., Chulaki, A., Gombosi, T. I. 2016, "Data Constrained Coronal Mass Ejections in A Global Magnetohydrodynamics Model", ApJ, arXiv:1605.05360 05/2016, 30 pp.

41. Joshi, J.., Lagg, A.., Solanki, S.. K., Feller, A., Collados, M., D. Suárez, O., Schlichenmaier, R.., Franz, M.., Balthasar, H., Denker,…C., **Schmidt, D.,** et al. 2016, "Upper Chromospheric Magnetic Field of a Sunspot Penumbra: Observations of Fine Structure", A&A **596**, id A8, 8 pp.

42. Judge, P. G., Kleint, L., Sainz Dalda, A. 2015 "On Helium 1083 nm Line Polarization during the Impulsive Phase of an X1 Flare", ApJ **814** (2), id. 100, 11 pp.

43. **Komm, R.**, **González Hernández, I.**, **Howe, R.**, Hill, F. 2015, "Solar-Cycle Variation of Subsurface Meridional Flow Derived with Ring-Diagram Analysis", SoPh **290** (11), 3113-3136.

44. **Kowalski, A. F.**, Allred, J. C., Daw, A. N., Cauzzi, G., Carlsson, M. 2016, "The Atmospheric Response to High Nonthermal Electron Beam Fluxes in Solar Flares I: Modeling the Brightest NUV Footpoints in the X1 Solar Flare of 2014 March 29"**,** ApJ, eprint arXiv:1609.07390, 42 pp.

45. **Kowalski, A. F.**, Hawley, S. L., Carlsson, M., Allred, J. C., **Uitenbroek, H.**, Osten, R. A., Holman, G. 2015, "New Insights into White-Light Flare Emission from Radiative-Hydrodynamic Modeling of a Chromospheric Condensation," SoPh **290** (12), 3487-3523.

46. Krishna Prasad, S., Jess, D. B., Jain, R., Keys, P. H. 2016, "Time-dependent Suppression of Oscillatory Power in Evolving Solar Magnetic Fields", ApJ **823** (1), id. 45, 15 pp.

47. Kumar, B., Raja Bayanna, Ankala, Venkatakrishnan, P., Kuchandy Mathew, S. 2016, "Analy-sis of sudden variations in photospheric magnetic fields during a large flare and their influences in the solar atmosphere", RAA **16** (8), id. 129.

48. Kuridze, D., Mathioudakis, M., Christian, D. J., **Kowalski, A. F.**, Jess, D.B., Grant, S.D.T., Kawate, T., Simões, P. J. A., Allred, J. C., Keenan, F. P. 2016, "Observations and simulations of the Na I D1 line profiles in an M-class solar flare"**,** ApJ **832** (2), id.147, 8 pp.

49. Lagg, A., Lites, B., **Harvey, J.**, **Gosain, S.,** Centeno, R. 2015, "Measurements of Photospheric and Chromospheric Magnetic Fields, SSRv Online First, arXiv:1510.06865.

50. Lagg, A., Solanki, S. K., Doerr, H.-P.., Martínez González, M. J., Riethmüller, T., M Vera, C., …**Schmidt, D**. et al. 2016, "Probing deep photospheric layers of the quiet Sun with high magnetic sensitivity", A&A **596**, **id. A6, 13 pp.**

51. Li, T., Zhang, J., Ji, H. 2015, "Filament Activation in Response to Magnetic Flux Emergence and Cancellation in Filament Channels" SoPh **290** (6), 1687-1702.

52. Löhner-Böttcher, J., Bello González, N., Schmidt, W. 2016, "Magnetic field reconstruction based on sunspot oscillations", AN **337** (10), 1040.

53. Manrique González, S. J., Kuckein, C., A Yabar, P., Collados, M., Denker, C., Fischer, C.E., Gömöry, P., … **Schmidt, D.** et al. 2016, "Fitting peculiar spectral profiles in He I 10830 Å absorption features", AN **337** (10), 1057.

54. Martinez-Gonzales, M. J., Ramos, A., Arregui, I., Collados, M., Beck, C. A. R., de la Cruz Rodríguez, J. 2016, "On the Magnetism and Dynamics of Prominence Legs Hosting Tornadoes", ApJ **825** (2), id. 119.

55. Mein, P., **Uitenbroek, H.**, Mein, N., Bommier, V., Faurobert, M. 2016, "Fast inversion of Zeeman line profiles using central moments. II. Stokes V moments and determination of vector magnetic fields," A&A **591**, id. A64, 13 pp.

56. Monsue, T., **Hill, F.,** Stassun, K. G., "Temporal Evolution of Chromospheric Oscillations in Flaring Regions: A Pilot Study", ApJ **152** (4), id. 81, 11 pp.

57. Mordvinov, A., **Pevtsov, A. A., Bertello, L., Petrie, G. J. D.** 2016, "The reversal of the Sun's magnetic field in cycle 24", STP **2** (1), 3-13.

58. Murabito, M., Romano, P., Guglielmino, S. L., Zuccarello, F., Solanki, S. K. 2016, "Formation of the Penumbra and Start of the Evershed Flow", ApJ **825** (1), 75.

59. Murabito, M., Romano, P., Guglielmino, S. L., Zuccarello, F. 2016, "On the formation of a stable penumbra in a region of flux emergence in the Sun", ApJ, arXiv:1611.04749, 6 pp.

60. Nagovitsyn, Y. A., **Pevtsov, A. A.**, and Osipova, A. A. 2016, "Long-term variations in sunspot magnetic field - area relation", AN, eprint arXiv:1608.01132, 8 pp.

61. Nagovitsyn, Yu. A., **Pevtsov, A. A**., Osipova, A. A., Tlatov, A. G., Miletskii, E. V., Nagovitsyna, E. Yu. 2016, "Two populations of sunspots and secular variations of their characteristics," AstL **42** (10) 703-712.

62. Najita, J., Willman, B., Finkbeiner, D. P., Foley, R. J., Hawley, S., Newman, J. A., **Giampapa, M.**, … et al. 2016 , "Maximizing Science in the Era of LSST: A Community-Based Study of Needed US Capabilities", arXiv:1610.01661, 174 pp.

63. Nelson, C. J., Doyle, J. G., Erdélyi, R. 2016, "On the relationship between magnetic cancellation and UV burst formation", MNRAS **463** (2), 2190-2201.

64. Osten, R. A., **Kowalski, A.**, Drake, S. A., Krimm, H., Page, K., Gazeas, K., Kennea, J., Oates, S., Page, M., de Miguel, E., et al. 2016, "A Very Bright, Very Hot, and Very Long Flaring Event from the M Dwarf Binary System DG CVn", ApJ, in press.

65. Owens, M. J., **Cliver, E. W.**, McCracken, K. G., Beer, J., Barnard, L., Lockwood, M., Rouillard, A., Passos, D., Riley, P., Usoskin, I., et al. 2016, "Near-Earth heliospheric magnetic field intensity since 1750: 1. Sunspot and geomagnetic reconstructions", JGR **121**, 6048-6063.

66. Owens, M. J., Cliver, E. W., McCracken, K. G., Beer, J., Barnard, L., Lockwood, M., Rouillard, A., Passos, D., Riley, P., Usoskin, I., et al. 2016, "Near-Earth heliospheric magnetic field intensity since 1750: 2. Cosmogenic radionuclide reconstructions", JGR **121** (7), 6064-6074.

67. Pant, V., Mazumder, R., Yuan, D., Banerjee, D., Srivastava, A. K., Shen, Y. 2016, "Simultaneous Longitudinal and Transverse Oscillations in an Active-Region Filament", SoPh 291 (11), 3303-3315.

68. **Penn, M. J**, Krucker, S., Hudson, H., Jhabvala, M., Jennings, D., Lunsford, A., Kaufmann, P. 2016, "Spectral and Imaging Observations of a White-light Solar Flare in the Mid-infrared", ApL **819** (2), id. L30, 5 pp.

69. **Penn, M. J.,** Baer, R., **Bosh, R.,** Garrison, D, Gelderman, R, **Hare, H.,** Isberner, F., **Jensen, L., Kovac, S., McKay, M., Mitchell, A.,** Pierce, M., Ursache, A., Varsik, J., Walter, D., Watson, Z., Young, D., and the Citizen CATE Team, 2016, "Instrumentation for the Citizen CATE Experiment: Faroe Islands and Indonesia", arXiv:1609.00035, 15 pp.

70. **Penn, M. J., Uitenbroek, H.**, Clark, Al., Coulter, R., Goode, P., Cao, W. 2016, "Spectro-polarimetry of Atomic and Molecular Lines near 4135 nm", SoPh **291** (8), 2243-2252.

71. **Petrie, G. J. D.** 2016, "Photospheric and Coronal Observations of Abrupt Magnetic Restructuring in Two Flaring Active Regions", SoPh **291**(3): 791.

72. **Petrie, G. J. D.** 2015, "On the Enhanced Coronal Mass Ejection Detection Rate since the Solar Cycle 23 Polar Field Reversal", ApJ **812** (1), id. 74, 14 pp.

73. **Petrie, G. J. D.** 2015, "Solar Magnetism in the Polar Regions", LRSP **12** (1), id.5, 102 pp.

74. **Pevtsov, A. A.**, Nagovitsyn, Y. A., Tlatov, A. G., Demidov, M. L. 2016, "Solar Physics Research in the Russian Subcontinent - Current Status and Future", AsJPh **25**.

75. **Pevtsov, A. A.**, Virtanen, I., Mursula, K., Tlatov, A.G., and Bertello, L. 2016, "Reconstructing solar magnetic fields from historical observations: I. Renormalized Ca K spectroheliograms and pseudo-magnetogram", A&A **585** id. A40, 9 pp.

76. **Pevtsov, A. A.** 2016, "The Vorticity of Solar Photospheric Flows on the Scale of Granulation", Ge&Ae, arXiv:1606.01390, 11 pp.

77. Predoi-Cross, A., Devi, V. M., Sung, K., Sinyakova, T., Buldyreva, J., Benner, D. C., Smith, M. A. H., Mantz, A. W. 2015, "Temperature dependences of N_2-broadening and shift coefficients in the nu_6 perpendicular band of $^{12}CH_3D$" JQSRT **163**, 120-141.

78. Ramesh, K. B., Vasantharaju, N., Hemanth, P., **Reardon, K.** 2016, "Solar dynamics imaging system a back-end instrument for the proposed NLST", ExA **42** (3), 271–283.

79. Rasca, A. P., Chen, J., **Pevtsov, A. A.** 2016, "Pixel Analysis of Photospheric Spectral Data. I. Plasma Dynamics," ApJ **832** (1), id. 53, 21 pp.

80. Rezaei, R., **Beck, C.** 2015, "Multiwavelength spectropolarimetric observations of an Ellerman bomb", A&A **582**, id.A104, 13 pp.

81. Rubio da Costa, F., Kleint, L., Petrosian, V., Liu, W., Allred, J. C. 2016, "Data-driven Radiative Hydrodynamic Modeling of the 2014 March 29 X1.0 Solar Flare", ApJ **827** (1), id. 38, 14 pp.

82. Santos, A. R. G., Cunha, M. S., Avelino, P. P., Chaplin, W. J., Campante, T. L. 2016, "On the contribution of sunspots to the observed frequency shifts of solar acoustic modes", MNRAS **461** (1), 224-229.

83. **Schad, T.A., Penn, M.J.,** Lin, H., Judge, P. G. 2016, "Vector magnetic field measurements along a cooled stereo-imaged coronal loop", ApJ, arXiv:1610.05332, 16 pp.

84. Schlichenmaier, R., von der Lühe, O., Hoch, S., Soltau, D., Berkefeld, T., **Schmidt, D.**, Schmidt, W., Denker, C., Balthasar, H., Hofmann, A., et al. 2016,"Active region fine structure observed at 0.08 arcsec resolution", A&A **596**, id. A7, 10 pp.

85. Shetye, J., Doyle, J. G., Scullion, E., Nelson, C. J., Kuridze, D., Henriques, V., **Woeger, F.**, Ray, T. 2016, "High-cadence observations of spicular-type events on the Sun", A&A **589**, id.A3, 15 pp.

86. Simoniello, R., **Tripathy, S. C., Jain, K., Hill, F.** 2016, "A New Challenge to Solar Dynamo Models from Helioseismic Observations: The Latitudinal Dependence of the Progression of the Solar Cycle", ApJ **828**(1): id.41.

87. Sobotka, M., Dudík, J., Denker, C., Balthasar, H., Jurcák, J., Liu, W., Berkefeld, T., M Vera, C., Feller, A., Hofmann, A.,…**Schmidt, D.** et al. 2016, "Slipping reconnection in a solar flare observed in high resolution with the GREGOR solar telescope", A&A **596**, id. A1, 6 pp.

88. Sobotka, M., Heinzel, P., Svanda, M., Jurcák, J., del Moro, D., Berrilli, F. 2016 "Chromospheric Heating by Acoustic Waves Compared to Radiative Cooling" ApJ **826** (1), id. 49, 8 pp.

89. Tlatova, K. A., Vasil'eva, V. V., **Pevtsov, A. A.** 2015, "Long-term variations in the sunspot magnetic fields and bipole properties from 1918 to 2014", Ge&Ae **55** (7), 896-901.

90. **Tripathy, S. C.** 2016, "Predictions of solar cycle", AsJPh **25** (3), 387-410.

91. **Tritschler, A., Rimmele, T. R., Berukoff, S. J.,** Casini, R., Kuhn, J. R., and Lin, H. 2016, "Daniel K. Inouye Solar Telescope: High-resolution Observing of the Dynamic Sun", AN **337** (10), 1064.

92. Varela, J., Pantellini, F., Moncuquet, M. 2016 "Parametric study of the solar wind interaction with the Hermean magnetosphere for a weak interplanetary magnetic field", P&SS **120**, 78-86.

93. Verma, M., Denker, C., Balthasar, H., Kuckein, C., Manrique, S.J. González, Sobotka, M., N Gonzalez, B., Hoch, S., Diercke, A., Kummerow, P., **Schmidt, D.** et al. 2016, "Horizontal flow fields in and around a small active region – The transition period between flux emergence and decay", A&A **596**, id. A3, 12 pp.

94. **Watson, F. T., Beck, C., Penn, M. J., Tritschler, A., Pillet, V. M., Livingston, W. C.** 2015, "Cross-Calibrating Sunspot Magnetic Field Strength Measurements from the McMath-Pierce Solar Telescope and the Dunn Solar Telescope," SoPh **290** (11), 3267-3277.

95. **Watson, F. T.** 2016, "Photospheric and Coronal Observations of Abrupt Magnetic Restructuring in Two Flaring Active Regions", SoPh **291**(3), 791-821.

96. Weinzierl, M., Mackay, D., Yeates, A., **Pevtsov, A. A.** 2016, "The Possible Impact of L5 Magnetograms on Non-Potential Solar Coronal Magnetic Field Simulations", ApJ **828** (2).

Conference Proceedings and Other Publications (47)

1. Admiranto, A. G., Priyatikanto, R., Yus'an, U., Puspitaningrum, E. 2016, "Moreton waves and EIT waves related to the flare events of June 3, 2012 and July 6, 2012", Proc AIP Conference **1677** (1), id.050014, arXiv:1502.04039.

2. Anusha, L. S., Nagendra, K. N., **Uitenbroek, H.** 2015 "Study of resonance scattering polarization in O i 130 nm lines", Proc. IAU **10**, 234-237).

3. Berkefeld, T., **Schmidt, D.**, Soltau, D., Heidecke, F., and Fischer, A. 2016, "The adaptive optics system of the 1.5m GREGOR solar telescope: four years of operation", Adaptive Optics Systems V, Proc SPIE **9909**: 990924.

4. **Bertello, L., Pevtsov, A. A.**, Tlatov, A. G. 2016, "Long-term Synoptic Observations of Ca II K and Magnetic Flux", Coimbra Solar Physics Meeting: Ground-based Solar Observations in the Space Instrumentation Era, ASP Conf. Ser. **504**, University of Coimbra, Coimbra, Portugal In 5-9 October 2015: 29.

5. **Berukoff, S. J., Hays, T., Reardon, K. P., Spiess, DJ., Watson, F.**, and **Wiant, S.** 2016, "Petascale cyber infrastructure for groundbased solar physics: approach of the DKIST data center", Software and Cyberinfrastructure for Astronomy IV, Proc SPIE **9913**, in press.

6. Bisi, M. M., Americo Gonzalez-Esparza, J., Jackson, B. V., Tokumaru, M., **Leibacher, J.** 2015, "Preface: Radio Heliophysics: Science and Forecasting", SoPh **290** (9), 2393-2396.

7. Charbonneau, P., **Leibacher, J**., Mandrini, C., van Driel-Gesztelyi, L., Wheatland, M. S. 2016, "Editorial: 50 Years of Solar Physics", SoPh **291** (12), 3461-3465.

8. **Craig, S. C., Gonzales, K. L., Hubbard, R. P., Liang, C., Kneale, R. A., McBride, W. R., Sekulic, P.**, and **Williams, T. R**. 2016, "Daniel K. Inouye Solar Telescope: the latest integration, testing, and commissioning plan", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press.

9. Egeland, R., Soon, W., Baliunas, S., Hall, J. C., **Pevtsov, A. A.**, and Henry, G. W. 2016, "Dynamo Sensitivity in Solar Analogs with 50 Years of Ca II H & K Activity", The 19th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, arXiv, Uppsala, Sweden, 06-10 June 2016.

10. Egeland, R., Soon, W., Baliunas, S., Hall, J. C., **Pevtsov, A. A.,** Henry, G. W. 2016 "The Solar Dynamo Zoo", The 19th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun, arXiv, Uppsala, Sweden, 06-10 June 2016, id. 72.

11. Egeland, R., Soon, W., Baliunas, S., Hall, J. C., **Pevtsov, A. A., Bertello, L.** 2016, "The Mount Wilson Observatory S-index of the Sun", ArXiv:1611.04540.

12. Fehlmann, A., Giebink, C., Kuhn, J. R., Messersmith, E. J., Mickey, D., Scholl, I., James, D., Hnat, K., Schickling, G., and Schickling, R. 2016, "Cryogenic near infrared spectropolarimeter for the Daniel K. Inouye Solar Telescope", Instrumentation for Astronomy VI, Proc SPIE 9908, in press.

13. **Ferayorni, A., Beard, A., Gregory, B. S., Cole, W., and Wöger, F.** 2016**,** "Bottom-up laboratory testing of the DKIST Visible Broadband Imager (VBI)", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press.

14. **Giampapa, M.S.** 2016, "Photometric Variations In The Sun And Solar-Type Stars", The 19th Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun (CS19), Uppsala, Sweden, 06-10 June 2016 (Session Splinter Session on "Variability of Solar/Stellar Magnetic Activity" , Part Part I.1), eds. Feiden, G., Fabbian, D., Simoniello, R., Collet, R., **Criscuoli, S**., Korhonen, H., Krivova, N., Oláh, K., Shapiro, A., Vidotto, A., Vitas, N..

15. Gorman, M. M. K., **Phelps, L. E., Montijo, Jr., G., Galapon, C.,** and Murga, G. 2016, "Cooling a solar telescope enclosure: plate coil thermal analysis", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press, 2016.

16. **Harrington**, D. 2016, "System polarization modeling and calibration strategies for the DKIST", Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation, Proc SPIE 9912, in press.

17. **Hubbard, R. P., Craig, S. C., and Kneale, R. A.** 2016, "Daniel K. Inouye Solar Telescope systems engineering update", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press.

18. **Hughes, A. L. H., Bertello, L., Marble, A. R., Oien, N. A., Petrie, G. J. D., Pevtsov, A. A.** 2016, "HMI Synoptic Maps Produced by NSO/NISP", National Solar Observatory, Technical Report No. NSO/NISP-2016-02, arXiv:1605.03500.

19. **Hughes, A. L. H., Jain, K.., Kholikov, S.,** and the **NISP Group** 2016, "GONG ClassicMerge: Pipeline and Product, National Solar Observatory, Technical Report No. NSO/NISP-2016-01, arXiv160300836H.

20. **Jeffers, P.,** Trieloff, T., Kärcher, H. J., Seubert, S., **McBride, W. R.** 2016, "DKIST telescope mount factory testing overview and lessons learned", Ground-based and Airborne Telescopes VI, Proc SPIE 9906, in press.

21. **Johnson, L. C., Cummings, K., Drobilek, M., Gregory, B. S., Hegwer, S. L., Johansson, E. M., Marino, J., Richards, K., Rimmele, T. R., Sekulic, P.**, et al 2016, "Status of the DKIST system for solar adaptive optics", Adaptive Optics Systems V, Proc SPIE 9909, in press.

22. Kim, D., Oh, C-J., Lowman, A. E., Smith, G. A., Aftab, M., Burge, J. H. 2016, "Manufacturing of super-polished large aspheric/freeform optics", Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation, Proc SPIE 9912, in press.

23. **Leibacher, J.**, Sakurai, T., van Driel-Gesztelyi, L. 2016, "Editorial Appreciation", SoPh **291** (2), 337-338.

24. Löhner-Böttcher, J. 2016, "Wave phenomena in sunspots", PhD Thesis, Universität Freiburg im Breisgau, 2016 03/2016

25. **Marino, J., Carlisle, E., Schmidt, D.** 2016, "Simulation of DKIST solar adaptive optics system", Adaptive Optics Systems V, Proc SPIE 9909: 99097C.

26. **Mayer, C., Wampler, S. B., Goodrich, B. D.** 2016, "World coordinate information for the DKIST", Software and Cyberinfrastructure for Astronomy IV, Proc SPIE 9913, in press.

27. **McBride, W. R**., and McBride, D. R. 2016, "Using frequency response functions to manage image degradation from equipment vibration in the DKIST", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press.

28. **McBride, W. R., Jeffers, P., Marshall, H. K**., 2016, "Vibration measurements of the DKIST mount, Coude rotator, and enclosure assemblies", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press, 2016.

29. **McMullin, J. P., Rimmele, T. R., Warner, M., Pillet, V. M.,** Casini, R.**, Berukoff, S. J., Craig, S. C., Elmore, D. F., Ferayorni, A., Hubbard, R. P.**, et al., 2016, "Construction status of the Daniel K. Inouye Solar Telescope", Ground-based and Airborne Telescopes VI, Proc SPIE 9906, in press.

30. **McMullin, J. P., Warner, M., Rimmele, T. R., Craig, S. C., Ferayorni, A., Goodrich, B. D., Hubbard, R. P., Hunter, R., Jeffers, P., Johansson, E. M.**, et al., 2016, "Project management and control of the DKIST", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press.

31. **McQuillen, I., Phelps, LE., Warner, M., Hubbard, R. P.** 2016, "Daniel K. Inouye Solar Telescope: computational fluid dynamics analysis and evaluation of the air knife model", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press.

32. Meftah, M., Corbard, T., Hauchecorne, A., Irbah, A., Boumier, P., Chevalier, A., ... **Kholikov, S.**, Koller, S., et al. 2016, “Main results of the PICARD mission”, Proceedings of the SPIE, Volume 9904, id. 99040Z 14 pp.

33. Montilla, I., **Marino, J.**, Asensio Ramos, A., Collados, M., Montoya, L., Tallon, M. 2016, “Solar adaptive optics: specificities, lessons learned, and open alternatives”, Proceedings of the SPIE, Volume 9909, id. 99091H 10 pp.

34. **Pevtsov, A. A.** 2016, “The Need for Synoptic Solar Observations from the Ground”, Coimbra Solar Physics Meeting: Ground-based Solar Observations in the Space Instrumentation Era Proceedings of a Meeting held at the University of Coimbra, Coimbra, Portugal In 5-9 October 2015, eds. I. Dorotovic, C. E. Fischer, and M. Temmer. ASP Conf. Ser. **504**, p.71.

35. **Schmidt, D.**, Gorceix, N., **Marino, J**., Berkefeld, T., **Rimmele, T. R.**, Zhang, X., **Wöger, F.,** Goode, P. R. 2016, "Progress in multi-conjugate adaptive optics at Big Bear Solar Observatory", Adaptive Optics Systems V, Proc SPIE 9909: 990929.

36. **Schmidt, D., Rimmele, T. R., Marino, J., Wöger, F.** 2016, "A review of solar adaptive optics", Adaptive Optics Systems V, Proc SPIE 9909: 99090X.

37. Schmidt, W., Schubert, M., Baumgartner, J., et al 2016, "End-to-end simulations of the visible tunable filter for the DKIST", Instrumentation for Astronomy VI, Proc SPIE 9908, in press.

38. **Sekulic, P., Liang, C., Gonzales, K. L., Hubbard, R. P., Craig, S. C.** 2016, "Daniel K. Inouye Solar Telescope optical alignment plan", Ground-based and Airborne Telescopes VI, Proc SPIE 9906, in press.

39. Sigwarth, M., Kentischer, T. J., Schmidt, W., et al. 2016, "Development of high reflectivity coatings for large format Fabry-Perot etalons", Instrumentation for Astronomy VI, Proc SPIE 9908, in press.

40. **Sueoka, S. R.**, **Harrington, D. 2016,** "Progress in modeling polarization optical components for the DKIST", Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation, Proc SPIE 9912, in press.

41. Verma, M., Denker, C., Balthasar, H., Kuckein, C., Manrique, S.J. González, Sobotka, M., N Gonzalez, B., Hoch, S., Diercke, A., Kummerow, P., et al. 2016, "Flows in and around Active Region NOAA12118 Observed with the GREGOR Solar Telescope and SDO/HMI", Coimbra Solar Physics Meeting: Ground-based Solar Observations in the Space Instrumentation Era, ASP Conf. Ser. **504**, 29, University of Coimbra, Coimbra, Portugal In 5-9 October 2015.

42. Veronig, A. M., Pötzi, W. 2016, “Ground-based Observations of the Solar Sources of Space Weather”, Coimbra Solar Physics Meeting: Ground-based Solar Observations in the Space Instrumentation Era Proceedings of a Meeting held at the University of Coimbra, Coimbra, Portugal In 5-9 October 2015, eds. I. Dorotovic, C. E. Fischer, and M. Temmer. ASP Conf. Ser. **504**, p.247.

43. **Warner, M.,** Summers, R. T. 2016, "The seven habits of highly effective project managers", Modeling, Systems Engineering, and Project Management for Astronomy VI, Proc SPIE 9911, in press.

44. **Watson, F., Reardon, K. P., Berukoff, S. J., Spiess, DJ., Wiant, S., Hays, T.** 2016, "Calibration development strategies for the DKIST Data Center", Strategies, Processes, and Systems VI, Proc SPIE 9910, in press.

45. White, C., **Phelps, L. E.** 2016, "DKIST facility management system integration", Ground-based and Airborne Telescopes VI, Proc SPIE 9906, in press.

46. **Williams, T. R., Hubbard, R. P.** 2016, "Integration of functional safety systems on the Daniel K. Inouye Solar Telescope", Ground-based and Airborne Telescopes VI, Proc SPIE 9906, in press.

47. **Wöger, F., Sekulic, P., Gregory, B. S., Hegwer, S. L., Ferayorni, A.** 2016, "DKIST visible broadband imager alignment in laboratory: first results", Instrumentation for Astronomy VI, Proc SPIE 9908, in press.

APPENDIX E. MILESTONES FY 2017

This section describes the major project milestones for 2017.

E1. Daniel K. Inouye Solar Telescope (DKIST)

- **Carryover**
  - M1 Cell Assembly FAT
  - WFC FDR
  - Enclosure SAT
  - S&O BOD
  - WFC CV System Validation
  - FIDO PDR
- **2017**
  - Commission TCS control of Enclosure
  - Coude Installation Complete
  - Mount Commissioning Complete
  - Coat Science M1
  - PA&C FDR
  - VBI Science Camera Integration Testing Complete

E2. DKIST Data Center Development

E2.1 Data Center Milestones

- Complete Conceptual Design Review (CoDR) (1Q FY17)
- Complete Preliminary Design Review (PDR) (2Q FY17)
- Complete Final Design Review (FDR) (3Q FY17)
- Demonstrate Provisioning and Orchestration System (4Q FY17)

E2.2 DKIST Instrument and Operations Tools Development

- Complete Operational Tools Science Requirements (2Q FY17)
- Complete Operational Tools Engineering Design Requirements (3Q FY17)
- Complete Operational Tools Preliminary Design Review (4Q FY17)
- Completion of the AO simulation software package. The simulation package is expected to be in a sufficiently developed state where it can be used routinely and possibly distributed.

- Finish simulation study of the MCAO performance applied to the system developed at BBSO. The study will explore the effects of different wavefront sensing geometries and the effects of different atmospheric configurations.
- Finish simulation study of DKIST adaptive optics performance. Explore system performance under a range of parameters, such as seeing conditions and reconstruction methods.
- Conduct 2-3 on-sky observing campaigns with solar MCAO at the BBSO NST. Develop improved strategy for dealing with the continuously evolving solar image structure seen the wavefront sensor.
- Perform numerical simulations to predict MCAO and ground-layer AO performance in different seeing situations, and to assess and to further improve the control loop performance and stability.
- Initiate collaboration with Andres Guesalaga (Pontificia Universidad Católica de Chile) to utilize Gemini SLODAR turbulence profiling method for MCAO at BBSO and eventually DKIST. Continue student training.

E4. NISP/SOLIS

- Installation of SOLIS canopy remote open/close control.
- Completion of VXWorks removal from remaining SOLIS instruments.
- Complete installation of visible tunable filter (VTF) and pre-filters into SOLIS Full-Disk Patrol (FDP) instrument.
- Complete Guider signal from Vector SpectroMagnetograph (VSM) instrument to VSM M2 fast tip/tilt mirrors.
- Implement Guider error from VSM instrument to VSM declination drive.
- Prepare and relocate SOLIS from GONG Farm to new selected site.

E5. NISP/GONG

- Relocate GONG test sites TE and TC from GONG Farm to CU-Boulder campus.
- GONG refurbishment, 2-year program.
- Install new Hα tunable filters.
- Install new cameras with new 1K x 1K detectors.
- Replace tunable modulators with new, tighter tolerance modulators.
- Replace aging optical elements.
- Upgrade Data Center for new Hα and additional data cluster storage.
- Enhance network bandwidth at GONG sites.
- Replace Hα and GONG workstations.
- Replace wind birds with new ultrasonic anemometer.

- Replace UPS interfaces.
- Update remaining GONG shelters and split unit HVAC units.
- Provide preventive maintenance kits, supplies, and spares for the next 10 years of site support.

E6. NISP Data Center (DC)

- Install new NISP DC hardware in Boulder.
- Transition NISP DC production operations to Boulder.
- Relocate remaining NISP DC staff to Boulder.
- Complete installation of GONG space weather pipelines at NOAA.
- Complete improvements to GONG zeropoint pipeline.
- Implement alternative VMBICAL processing due to staff retirement.

E7. Virtual Solar Observatory (VSO)

- Complete installation of VSO's NSO node in Boulder.
- Continue to incorporate data sets into the VSO by developing new data provider software, as well as maintaining existing data providers.
- Improve system robustness by developing autonomous monitoring systems.
- Continue to investigate methods for upgrading the user interface.
- Continue to investigate spatial searching techniques.

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.
- 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
- Maintain user-friendly data reduction/calibration software, provide software support to users.
- Install thermal control for LCVR modulation unit in Infrared branch for more accurate polarimetry.

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.
- Provide first draft of plan to ugrade telescope control to more modern technology, in preparation to handover of telescope to the NMSU consortium at the end of FY 2017.

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.
- Provide option and connectivity to run instrument from the DST control room, aka the bridge.

E13. Establish NSO Headquarters

- *Hire a Business Manager for Operations.*
- *Implement matrix structure for administrative personnel.*
- *Establish IT program for Headquarters (e-mail servers, web servers, etc.).*
- *Continue developing basic infrastructure for scientific support.*
- *Fill second CU-NSO shared faculty position.*
- *Continue implementing transition plan.*

APPENDIX F. STATUS OF FY 2016 MILESTONES

This section describes the progress of current projects relative to the milestones established in the FY 2016 Program Plan. (FY 2016 milestones appear in italics below.)

F1. Daniel K. Inouye Solar Telescope (DKIST)

- ♦ *M1 Final Blank Polishing Acceptance*
  - Achieved. FAT was completed in December 2015, meeting all specifications; currently the M1 is in storage at Davis Monthan Air Force Base for planned transport to the summit in 2017.
- ♦ *M1 Cell Assembly Factory Acceptance Testing (FAT)*
  - Incomplete. The issues discovered during the initial FAT testing took substantial time to resolve. The major thermal tests are now complete and successful. There was substantial float in this schedule but the delays have used much of this time. At the project's insistence, additional qualified staff have been dedicated to the FAT which is now scheduled for January 2017 (with no impact on the critical path).
- ♦ *Start Coudé Rotator Installation*
  - Achieved. Following successful discussions with pertinent unions, the team was established and assembly began in December 2015. The assembly and installations are well along with anticipated 'start-up' in January 2017 and completion of commissioning in May 2017.
- ♦ *PA&C PDR*
  - Achieved. The PDR was completed in June 2016 with no identified technical obstacles; a range of actions were proposed to facilitate the path to an FDR, in particular refining the polarization calibration planning and a technical review of long-lead items to ensure adequate schedule for the system.
- ♦ *WFC FDR*
  - Incomplete. The FDR has been delayed into 2017 principally as a concession to relocations of the team to Boulder and a focus on the laboratory setup and testing as well as some deficiencies in early received components requiring focus and ultimately re-work.

FY 2016

- ♦ *Start Telescope Mount Installation*
  - Achieved. The preparation for the mount base installation began in June and in August 2016, the first mount bearing base components were placed.
- ♦ *Start ROB construction in Pukalani*
  - Incomplete. Bids for the construction were received at the end of August 2016 with a planned start of construction in early 2017 with an anticipated one year for completion. There is no impact on the project critical path.
- ♦ *Enclosure Site Fabrication Complete*
  - Incomplete. There are residual mechanical and electrical punch list items that are being performed prior to the formal Site Acceptance Testing. In addition, some quality assurance

issues were discovered during early testing which required remediation. The project has re-organized effort to complete this work but there is no impact on the critical path

- *Support & Operations Building BOD*
  - Incomplete. Although the building is in use by the teams, we have not claimed this milestone. Delays (principally driven by weather) pushed the achievement of the weather tight milestone which consequentially delayed some interior electrical and fit and finish activities (dry wall interiors, painting, etc). In addition, labor issues within the FTS team have led to delays in some key installations needed for the fit and finish work. This is scheduled to be complete in 2017 (with no impact on the critical path).
- *M10 DMS Performance Testing*
  - Achieved. The WFC team made significant progress in this area (reproducing the FAT testing in the Boulder lab, and running the testing under real-time controls).
- *WFC CV System Validation*
  - Incomplete. The WFC has also made significant progress on the optics and opto-mechanics testing, characterizing the objective lenses and the flat mirrors in their mounts. The completion of testing has pushed to January 2017 (with no impact on the critical path).
- *Facility Instrument Distribution Optics PDR*
  - Incomplete. This area had substantial float but was not adequately developing. The project transitioned responsibility for this area and is currently holding monthly meetings to drive it to a PDR in early 2017 (with no impact on the critical path).
- *Instrument Control System – VBI integration*
  - Achieved. In April 2016, the integration was completed with test execution of VBI programs through the ICS interface (including full data rates of 30 fps going through the system from the camera simulator to the final DHS and use of VBI operator configuration screens).
- *VBI Speckle Prototype Release*
  - Achieved. Development and testing concluded in August 2016.
- *DHS Quality Assurance System – Display Tool*
  - Achieved. Development completed in September 2016; user acceptance testing is planned for early 2017.
- *Facility Control System Design Review*
  - Incomplete. This is a non-critical path activity which has been shifted to accommodate resources on higher priority areas.

F2.1 DKIST Data Center Milestones

- *Complete Data Center Operational Concepts Definition (1Q FY17)*
  - Milestone complete.
- *Complete Project Execution and Management Plans (2Q FY17)*
  - 70% complete. Will be completed 100% for Conceptual Design Review Nov. 16

- *Successfully conclude Data Center Conceptual Design Review (2Q FY17)*
  - CoDR is scheduled for March 17.
- *Successfully conclude Data Center Preliminary Design Review (4Q FY17)*
  - PDR shifted to 4Q FY17. Q4 arrival of FY15 funding has led to corresponding delay of DC development.
- *Successfully conclude Data Center Final Design Review (2Q FY18)*
  - Shifted to 2Q FY18. Q4 arrival of FY15 funding has led to corresponding delay of DC development.

F2.2 DKIST Instrument and Operations Tools Development

Operations Tools Development

- *Complete Operational Tools Operational Concept Definition (OCD) and Use Cases (2Q FY16)*
  - Milestone complete.
- *Complete Operational Tools High-Level Requirements and Traceability (3Q FY16)*
  – Successfully conduct requirements review (3Q FY16)
  - Requirements 25% complete. Review scheduled for 3Q FY17. Q4 arrival of FY15 funding has led to corresponding delay of Operations tools development.
- *Complete Operational Tools Design Requirements and Traceability (4Q FY16)*
  – Successfully Conduct Preliminary Design Review (4Q FY16)
  - Requirements 10% complete. Design Review scheduled for Q3 FY17.
    Q4 arrival of FY15 funding has led to corresponding delay of Operations tools development.

F4. NISP/SOLIS

- *Select site for SOLIS relocation.*
  - In process. Two final sites contending for SOLIS. Final replies for considerations expected 1Q FY17 to determine site selection.
- *Start SOLIS relocation permitting process*
  - In process. Anticipating response in Oct. 2016.
- *Begin SOLIS site preparation when permitting process is complete.*
  - In process. Plans have been put in place for site preparation, which include ROM estimates from contractors generated.
- *Initiate VSM 8542 vector observations.*
  - Completed. Installation of new 8542 vector modulator successful. Observations have been ongoing since summer 2016; this includes full-disk scans and IRIS area scans, when available.
- *Implement VSM 8542 vector data reduction.*

- Complete. Quick-look 8542v magnetograms are now provided as part of our automated pipeline processing. A modified center-of-gravity approach is used to estimate the field strength, while the inclination and azimuth are calculated using the approaches of Auer, Heasley, and House (1977) and Ronan, Mickey, and Orrall (1987), respectively.

♦ *Install FDP visible tunable filter (VTF).*

- In process. VTF has been tested and tuned in lab. Installation into FDP scheduled for 1Q FY17.

♦ *Implement FDP VTF data reduction.*

- Deferred. Installation of the FDP VTF is a requisite precursor to this milestone.

♦ *Install new Integrated Sunlight Spectrometer (ISS) camera.*

- In process. Software conversion for DAS has been developed. Installation of camera scheduled for beginning of 2Q FY17.

♦ *Remove VXWorks from SOLIS operating system.*

- In process. VXWorks has successfully been replaced in the FDP. The Mount, VSM, and ISS are scheduled for 1Q and 2Q FY17.

♦ *Complete Mount Guider DEC loop.*

- In process. DEC guider loop on FDP successfully implemented. VSM guider loop for RA currently being implemented into SOLIS Mount. DEC guider loop on VSM scheduled for 2Q FY17.

F5. NISP/GONG

♦ *Purchase new Data Center hardware.*

- Complete. All components of the NISP Data Center Relocation: Hardware Plan were procured in FY16.

♦ *Install hardware at Tucson; test and copy data.*

- Complete. The new NISP Data Center hardware was installed and tested in temporary space provided within the NOAO server room. NISP's data archives have been copied to the new data storage cluster,

♦ *Dismantle and ship system to Boulder.*

- Deferred. The NISP Data Center hardware is being relocated to the University of Colorado's SPSC Data Center. This milestone was originally intended to be met in April 2016; however, construction delays on the part of CU have pushed this hardware relocation back to the end of 2016.

♦ *Integrate system in Boulder.*

- Deferred. As previously stated, the relocation of the new NISP Data Center hardware to Boulder was delayed by CU. However, the effects of the delay are being mitigated by proceeding with software installation that was originally scheduled to be done after the relocation.

- *Install space weather data processing pipelines at NOAA SWPC-Boulder.*
  - In process. The H-alpha data processing pipelines have been installed and tested on a development server at NOAA. Installation of the magnetic field data processing pipelines has been on hold due to delays at NOAA. However, we have successfully installed those pipelines on our own virtual machine that replicates the NOAA development server.
- *Improve magnetic field zero-point pipeline.*
  - In process. Improvements to the magnetic field zero-point pipeline have been developed and are currently being tested. However, ultimately, it has been modifications to the data acquisition itself that have resulted in the most significant improvements to the magnetic field zero-point. Those modifications were implemented at five of the six GONG network sites in September 2016, and the eight weeks of observations (two solar rotations) required for proper evaluation are being collected.
- *Develop plan for GONG refurbishment.*
  - In process. Project plan for GONG refurbishment has been developed and is currently under way. Thirteen 2017 project milestones for GONG refurbishment have been outlined in E5 above.
- Develop SPRING proposal.
  - In process. The science requirements document is completed, and the final technical and design documents are still in preparation. The completed proposal documents are expected to be submitted to the European Research Council in March 2017. Proof-of-concept studies have been carried out at the German Vacuum Tower Telescope in Tenerife.

F6. Virtual Solar Observatory (VSO)

- *Upgrade VSO/NSO hardware and install in Boulder.*
  - In process. Replacement hardware (two servers) for the VSO node hosted at NSO was purchased and is being staged in Boulder. However, final networking configuration and installation in the CU SPSC Data Center is subject to the same aforementioned delays affecting the rest of the NISP Data Center hardware.
- *Continue to add data providers.*
  - Complete. Data providers have been added for an archive of HMI synoptic variance maps, an archive of composite maps served out by NGDC, and reprocessed IVM data served out of NWRA in Boulder. Additionally, UCAR's HAO data provider, which serves out MLSO data, was restored to operating status after previously falling into disrepair.
- *Develop new Web user interface.*
  - In process. Software techniques and toolkits for doing this are being investigated.
- *Start spatial subset search capability.*

- Deferred. Competing priorities have precluded progress on this project.

♦ *Complete reporting system.*

- In process. Development of the VSO monitoring system is ongoing, as is work on documentation.

F7. NSO Array Camera (NAC)

♦ *Polarimetric measurements at 3600 nm on solar disk.*

- Partially complete. Intensity scans on the solar disk were taken in an infrared Ca I line, but no polarization data was taken. The mid-IR polarization package was returned to NJIT/BBSO at their request and NSO has no capability to make these measure-ments. Currently the NAC instrument is suffering from a dewar vacuum leak, and with no McMP staff, there is no manpower to fix the instrument.

♦ *Polarimetric measurements at 3934 nm on solar disk and sky.*

- Incomplete. The borrowed mid-IR polarization package was returned to NJIT/BBSO, and the NAC camera is currently inoperable, and not likely to be repaired.

F8. Spectropolarimeter for Infrared and Optical Regions (SPINOR)

♦ *Rewrite instrument control software for direct control instead of trigger control, which is unreliable and difficult to maintain.*

- Accomplished.

♦ *Maintain instrument and keep available as user instrument.*

- Ongoing.

♦ *Keep instrument available to perform telescope matrix measurements over broad range of wavelengths.*

- Ongoing.

♦ *Upgrade instrument software to run under broader range of conditions.*

- Accomplished.

♦ *Maintain user-friendly data reduction/calibration software, provide software support to users.*

- Ongoing.

F9. Facility IR Spectropolarimeter (FIRS)

♦ *Maintain instrument and keep available as user instrument.*

- Ongoing.

♦ *Maintain user-friendly data reduction/calibration software, provide user support.*

- Ongoing.

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

- *Perform necessary maintenance to keep telescope available for the solar community.*
  - Ongoing.
- *Continue efforts to proactively upgrade telescope and other critical hardware systems to the extent possible given financial and personnel constraints.*
  - Ongoing.
- *Provide first draft of plan to ugrade telescope control to more modern technology, in preparation to handover of telescope to the NMSU consortium at the end of FY 2017.*
  - Ongoing.

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

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

F12. Interferometric Bidimensional Spectrometer (IBIS) Camera Upgrade

- *Maintain instrument and keep available as user instrument.*
  - Ongoing.
- *Maintain user friendly data reduction/calibration software, provide software support to users.*
  - Ongoing
- *Provide option and connectivity to run instrument from the DST control room, aka the bridge.*
  - Ongoing

F14. Establish NSO Headquarters

- *Sign MOU with CU Boulder.*
  - Achieved in September 2016.
- *Fill first CU-NSO shared faculty position.*
  - Achieved.
- *Finish furnishing all meeting rooms and provide them with AV equipment.*
  - Achieved.

- ♦ *Provide infrastructure for scientific support.*
  - In process.
- ♦ *Continue implementing transition plan.*
  - Ongoing.

APPENDIX G. NSO FY 2017 STAFFING SUMMARY

(In Full-Time Equivalents)

	Director's Office		NSO/Sunspot		NSO/Tucson	DKIST				NISP			TOTAL
	Tucson	*Boulder*	*Sunspot*	*Boulder*		*Tucson*	*Sunspot*	*Maui*	*Boulder*	*Tucson*	*Sunspot*	*Boulder*	
Scientists	1.20	1.00		1.00	1.20	0.80	1.00	3.00	9.00	2.75	1.00	6.00	27.95
Engineering/Science Support Staff	-	1.00	3.55			12.00	2.00	15.00	19.95	7.00		4.00	64.50
Administrative Staff	1.10	3.70	2.00			3.00	1.00	3.00				1.00	14.80
Technical Staff	0.25		3.74		0.25		1.00	11.50	1.00	3.75			21.49
Maintenance & Service Staff	-		2.30					1.00					3.30
Graduate Students													
Undergraduate Students	0.50	0.25				0.19							0.94
													0.00
Total Base Program	***3.05***	***5.95***	***11.59***	***1.00***	***1.45***	***15.99***	***5.00***	***33.50***	***29.95***	***13.50***	***1.00***	***11.00***	***132.98***
AF Supported Science Staff	-					-				-			0.00
AF Supported Technical Staff	-					-				-			0.00
Other NSF Projects (AO, FTS/CHEM)	-					-				-			0.00
Graduate Students (NASA Supported)	-					-				-	0.30		0.30
NASA Supported Science Staff	-					-				1.50			1.50
NASA Support Engineering Staff	-		-			-							0.00
NASA Supported Technical Staff	-		-			-				-			0.00
Emeritus Science Staff	-		2.00	2.00		-				-			4.00
Visiting Scientists	-		-			-				-			0.00
													0.00
Total Other Support			***2.00***	***2.00***						***1.50***	***0.30***		***5.80***
Total FTEs	**3.05**	**5.95**	**13.59**	**3.00**	**1.45**	**15.99**	**5.00**	**33.50**	**29.95**	**15.00**	**1.30**	**11.00**	**138.78**

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 spectro-polarimetry of the photosphere and chromosphere; development of inversion tools for chromospheric spectral lines.

Recent Research Results

Dr. Beck and colleagues published a paper on the properties of limb spicules (SoPh, 291, 2281, 2016) that is based on observational data taken over several years. Another paper, on the magnetic field in prominence feet resulting from a European collaboration was published as well (ApJ, 825, 119, 2016). He gave an invited talk on chromospheric spectropolarimetry at the 2015 AGU fall meeting. Most of Dr. Beck's effort has been on instrumental development at the Dunn Solar Telescope in collaboration with California State University, Northridge (CSUN). A subtractive double-pass setup and an integral field unit based on microlenses were successfully tested to convert the standard spectrograph of the DST to an imaging spectrometer. An extension to an imaging spectropolarimeter is planned for 2017 (Guo et al., RAA, in press).

Future Research Plans

To improve the Ca II inversion code, an archive of spectra was synthesized assuming non-local thermal equilibrium (non-LTE). Performance with the new archive will be verified in the near future. Beck and colleagues also plan to include magnetic fields and polarimetric observations into the next version of the code. The LTE version of the code is currently being used in a Masters thesis at CSUN for an implementation using field-programmable gate arrays and at Queen's University, Belfast as part of a PhD thesis. Dr. Beck's collaborations with CSUN will continue on both data analysis and instrumenta-tion development. Current plans include building a prototype spectropolarimeter based on a grating spectrograph that uses an integral field unit for possible deployment as a second-generation instrument for the Daniel K. Inouye Solar Telescope (DKIST).

Service

C. Beck is a member of the Sac Peak telescope allocation committee. He also performed several additional observation campaigns at the DST for external investigators. Dr. Beck's involvement in the DKIST project has increased in the Polarization Analysis & Calibration and Data Center groups for the development of data pipelines for the reduction of future DKIST observations. He expects to continue to commit 87.5% of his time to DKIST. During the past year, Beck has reviewed a few publications for *Astronomy & Astrophysics* and *The Astrophysical Journal*.

Luca Bertello, Scientist

Areas of Interest

Solar variability at different temporal, spectral, and spatial scales. Calibration of the observed solar magnetic field data to enhance the database that supports the analysis of conditions in the Sun's corona and heliosphere. Long-term synoptic observations in the resonance line of Ca II K for retrospective analyses of the solar magnetism on multi-decades time scales.

Recent Research Results and Plans for Future Research

Over the course of this year, Dr. Bertello has been involved in several projects related to the improvement of the NISP data catalog. A major task completed in 2016 was the reprocessing of the entire 6302L longitudinal magnetic field measurements back to 2003, the beginning of the SOLIS/VSM project. In addition, several results from his recent research activity have been published in a series of papers and presented at various venues. They include, among others, studies of the correlation between the chromospheric Ca II K index and the new sunspot number time series, the estimation and impact of uncertainties in the fully disambiguated SDO/HMI Carrington vector synoptic maps, and an investigation about using magnetic observations from the L5 advantage point of view. New projects started in 2016 include the following tasks: 1) the recalibration of several SOLIS/ISS spectral bands using a more advanced flat-fielding procedure and accounting for the contribution of scattered light; 2) The merging of longitudinal and full-Stokes measurements to produce more reliable Carrington synoptic maps of the photospheric magnetic field. This new product is expected to improve the diagnostic capability of current coronal and heliospheric models quite significantly; 3) In collaboration with other NISP scientists, a significant effort is underway to improve the zero-point correction in GONG magnetic field measurements; and 4) Working jointly with several other members of the solar and heliophysics community, an initial assessment of the importance of having a magnetograph in a L5 mission to improve space weather prediction capabilities has begun.

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. He is also involved in the analysis of chromospheric data from the full-Stokes 8542 modulator recently added to the VSM instrument. Dr. Bertello maintains strong collaborations with several national and international institutes. This synergy has grown consistently over the years, and has opened several new research channels.

Service

As the Data Scientist for SOLIS, Bertello's major responsibility is to provide the solar and heliophysics community with high-quality and reliable data. During 2016, Bertello has been a reviewer of publications for *Solar Physics* and other journals.

*Olga Burtseva, Assistant Scientist

Areas of Interest

Flares; magnetic fields; local helioseismology; solar activity.

Recent Research Results

Dr. Burtseva continues working on the evolution of magnetic field associated with solar flares. In collaboration with S. Gosain and A. Pevtsov, she had been working on cylindrical symmetry of round sunspots that could be used as a proxy for flare-related changes in pseudo-vector magnetic field derived from line-of-sight magnetograms, when vector data are not available. Vertical, radial, and tangential components of vector magnetic field as a function of the distance from the sunspot center have been reconstructed from LOS magnetic field observed by HMI for two sunspots at the X2.2 flare site in the NOAA active region 11158 on Feb 15, 2011 and their evolution around the time of the flare is compared with vector magnetic field data. Simple round sunspots are analyzed for validation of the technique. A paper on the results of this work is in preparation.

O. Burtseva has resumed analysis of flux cancellation events during major flares using HMI vector magnetic field data (in collaboration with G. Petrie). She has been also working on construction of synoptic maps of the pseudo-radial chromospheric magnetic field from SOLIS/VSM.

Future Research Plans

O. Burtseva plans to continue working on the synoptic maps product. She will also continue the flux cancellation study in conjunction with analysis of Doppler velocity shifts at the cancellation sites which might help to distinguish between physical processes that could stand behind flux removal from the photosphere in flaring active regions.

Serena Criscuoli, Assistant Astronomer

Areas of Interest

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

Recent Research Results

Dr. Criscuoli recently worked on topics in the framework of the 'Areas of Interests' mentioned above. In particular, she led two meetings of an international Team at ISSI, Bern, Switzerlad, "Toward New Modeling of Solar Spectral Irradiance with the Use of 3D MHD Simulations". The two meetings occurred in March and October of 2016, and were aimed at comparing radiative properties of MHD snapshots of the solar atmosphere as obtained by different codes, as well as comparing the mentioned radiative properties as obtained by different radiative transfer techniques. Dr. Criscuoli also employed MHD simulation of the solar photosphere to investigate variation of the solar limb darkening function over the 11-year magnetic cycle. Dr. Criscuoli also employed observational data to investigate the variation over the magnetic cycle of the distribution of faculae and network, to investigate the dynamic properties of sunspot penumbrae and the properties of a white light flare. The results of her investigations have been published in *Solar Physics* and *The Astrophysical Journal* and have been presented at international conferences.

Service

Dr. Criscuoli mentored an REU student during summer 2016. She is a member of the Sac Peak telescope allocation committee and is responsible for user support, as well as improvement, of the IBIS data calibration software. She is a scientific consultant for the DKIST and is responsible for developing one of DKIST's critical science cases. In 2016, she was a referee for scientific journals. She was also on the Scientific Organization Committee of the "2016 Solar and Heliophysics Italian Community, 2016" and of the splinter session, "Variability of Solar/Stellar magnetism", at the Cool Stars 19 Conference.

Mark S. Giampapa, Astronomer

Areas of Interest

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

Recent Research Results

With Vincenzo Andretta (INAF, Naples) and collaborators, a manuscript on the utilization of the He I triplet lines at 587.6 nm and 1083.0 nm for the measurement of active region area coverage in solar-type stars was recently submitted to *The Astrophysical Journal*. It is currently under revision in response to referees' comments. An interesting result of this work is that solar-type stars appear to have similar active region heating rates with differences in overall activity due mainly to the filling factor of plages. In collaboration with Kepler Project Scientist Steve Howell, Giampapa contributed Sun-as-a-star context for a paper on variability seen in solar-like exoplanet systems with terrestrial-size planets. In this paper, published in *The Astronomical Journal*, Giampapa demonstrated that subgiants were a preferred class of objects for transit detections. Giampapa published a refereed invited review of The Solar-Stellar Connection in *The Asian Journal of Physics*.

Future Research Plans

Dr. Giampapa is currently collaborating with A.–M. Cody (NASA-Ames) and J. Hall (Lowell Observatory) in an analysis of the magnetic activity and broad band photometric variability of solar-type stars in the solar-age and metallicity cluster, M67, which the *K2* mission completed monitoring for ~ 80 days in July 2015. Giampapa received both a NASA *K2* Guest Observer grant and an NN-EXPLORE grant to support the data analysis effort. The Ca II H&K data have been reduced while the *K2* time series data are undergoing analysis to discern rotation periods. In an approved NASA SOFIA program to measure starspot properties on solar-type stars with transiting exoplanets, Giampapa's team is waiting for observations to be scheduled. Proposals for a similar effort have been submitted to the NN-EXPLORE program and to the Galileo Telescope facility in the Canary Islands. The latter will focus on using exoplanet transits of active regions on the stellar surface to measure for the first time intrinsic heating rates in stellar plages.

Service

After 15 years as the Deputy Director for the National Solar Observatory, M. Giampapa now serves as the NSO Tucson Site Leader with the implementation of the new Cooperative Agreement. As Site Leader, he will continue to carry out his oversight of the NSO Tucson/Kitt Peak and Tucson program. 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 is a point of contact between the NSO the NOAO and LSST, respectively. As the first Diversity Advocate for the NSO, Giampapa continues to support the work of the current NSO Diversity Advocate, Dr. John Liebacher. Like other NSO scientific staff members, Giampapa participates in educational outreach activities. Giampapa is an adjunct astronomer at the University of Arizona.

Sanjay Gosain, Assistant Scientist

Areas of Interest

Solar Physics: Flares, eruptive filaments and coronal mass ejections (CMEs); chromospheric magnetic field of solar active regions; solar cycle evolution of magnetic field. Astronomical instrumentation: optical design of instruments for polarimetry and spectroscopy.

Recent Research Results:

Dr. Gosain's main research activities include:

Filament Eruption of October, 21, 2011 (ApJ, 821, 2, 2016): Observations of an eruptive quiescent filament associated with a halo Coronal Mass Ejection (CME) were analyzed. The kinematics of the eruptive filament were derived from observations taken by STEREO and SDO satellites. The two associated signatures of eruptive filaments, i.e., the CME in the coronagraph observations and chromospheric bright ribbons, both appeared after a significant delay. To understand the cause of this delay, we computed the decay index (n) of the overlying coronal magnetic field. The height distribution of the decay index, n, showed that the zone of instability (n > 1) at a lower altitude, 144–480 Mm, is followed by a zone of stability (n< 1) between 540 and 660 Mm. We interpreted the observed delay to be due to the presence of the latter zone, i.e., the zone of stability, which interrupted the ongoing eruption by providing a second equilibrium to the filament, until it finally erupted after the observed delay.

Spectropolarimetry in Chromospheric Ca II 854.2 nm spectral line: See Science Highlights Section 2.3 of this report for a description of this work.

Instrumentation / Service:

As part of the GONG refurbishment project, Dr. Gosain is heavily involved in the design, procurement, tests and laboratory calibration of optical components and the camera system. Currently he is leading design efforts for a new H-alpha imaging system with a tunable FP etalon which will replace existing non-tuned solid etalon system. Dr. Gosain is also involved in the collaborative Solar Physics Research Integrated Network Group (SPRING) project between NSO and Kiepenheuer Institute in Freiburg, Germany.

Future Research Plans & Service:

S. Gosain plans to carry out NLTE inversions of SOLIS Ca II 854.2 nm spectropolarimetric observations in a few chosen active regions to assess the force-freeness of the magnetic field at chromospheric heights. He will be heavily involved in the GONG refurbishment project activities. He would also complete the technical requirements document for the SPRING project.

David M. Harrington, DKIST Polarimetry Scientist

Areas of Interest

Instrumentation; spectropolarimetry, adaptive optics, novel optical systems, detector systems, applied research, community workforce development.

Recent Research Results

Dr. Harrington has been developing polarization system performance models, optical system models and calibration algorithms for large telescopes. He has also been working on the design and fabrication of a high precision lab spectropolarimeter for full Mueller matrix characterization of optics in the visible and near-IR. Other activities include: daytime sky polarization calibration technique development for large telescopes (AEOS, Keck, Dunn Solar Telescope); and data reduction and analysis pipelines for polarimetric instrumentation (HiVIS & InnoPOL on AEOS, LRISp on Keck, curvature adaptive optics and EMCCD imaging polarimeters).

Future Research Plans

Dr. Harrington is actively developing new techniques to calibrate, model and improve the polarimetric performance of astronomical telescopes and instruments. New lab equipment and methods are in development for characterizing and modeling large polarimetric optics. Software modeling improvements and new mathematical techniques will advance the state-of-the-art for calibration precision and accuracy. Applying new interdisciplinary techniques both from theory and components will keep DKIST on the cutting edge of technology. With DKIST first-light instruments and novel data sets, a wide range of science cases for a diverse community will be impacted by system improvements.

Service

Harrington is an active member of the DKIST Science Group and is the DKIST polarimetry scientist working with the Polarimetry Analysis & Calibration team to integrate and calibrate the first-light instrument suite. The DKIST user community is being engaged and educated in anticipation of the new DKIST polarimetric capabilities. Harrington is an active participant in the Akamai Workforce Initiative, which involves working with industry and academic partners, mentoring Hawaii-connected local interns for summer and year-long projects and facilitating connections between industry and various STEM-focused educational programs.

John W. Harvey, Astronomer

Areas of Interest

Solar magnetic and velocity fields; helioseismology; instrumentation.

Recent Research Results

During FY 2016, Dr. Harvey was employed half-time and worked mainly 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. In instrumental work, Harvey concentrated on plans to refurbish the GONG instruments for an additional ten years of operation. Three issues were addressed: A replacement camera for the 1996 vintage, obsolete cameras currently in service. Replace the existing H-alpha filters with tunable ones to allow Doppler motions to be detected to enhance space weather predictions. Reduction of errors in GONG magnetogram zero level. The latter issue received the most attention with a resulting improvement of about an order of magnitude. Before these urgent issues arose, Harvey started analysis of some unique 8542 Å chromospheric spectropolarimetric observations made with the SOLIS VSM. These high-sensitivity measurements showed that linear polarization of the line core is dominated by scattering polarization, thus obscuring the Zeeman effect except in strong magnetic field areas. Preliminary results were presented at a meeting and a paper is in the draft stage. Thanks to his Co-I position on a NASA Grand Challenge grant, geometric correction of 30 years of daily magnetograph data was a major effort working together with Andres Munoz-Jaramillo. Nearly all the magnetograms from 1974 – 2000 have been processed and work is underway on the 1991 – 2003 and 1970-1973 observations. This has greatly improved quality to nearly that of contemporary observations and will enable a wide range of improved solar cycle studies once the data is installed in the NSO data archive

Future Research Plans

During FY 2017, his final year of employment, J. Harvey will try to finish the 8542 paper while participating in the GONG refurbishment effort and SOLIS maintenance. . Harvey hopes to finally be able to concentrate more on research following his October 2014 transition to half-time. He is especially interested in using the archive of old magnetograms to estimate past meridional flow patterns in the solar photosphere. He is preparing his invited memoirs for the journal *Solar Physics*, which should be published in 2017. He is working with John Briggs on a paper that describes the first (1871) photograph of solar granulation. Harvey plans to apply for emeritus status in NSO.

Service

J. Harvey has responsible instrumental and scientific roles in the GONG and SOLIS projects and participates in the management of NISP. During FY 2016, he reviewed several journal papers and presented a public talk about the history of solar polarimetry in Magdalena, NM. 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.

Recent Research Results

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 up to mid 2016 still indicates that the poleward flow for Cycle 25 is very weak, suggesting that Cycle 25 will be delayed and weaker than cycle 24.

Hill has continued work with K. Jain, S. Tripathy, and R. Simoniello on cycle-related changes of the oscillation frequencies. These variations show a complex latitudinal dependence with the cycle starting at mid-latitudes and then migrating equatorward and poleward, while the old cycle is still ongoing below 15° latitude. This prolonged activity causes a delay in the onset of the cycle and an overlap of successive cycles.

Hill continues to participate in a NASA Grand Challenge (P. Martens, PI, Georgia State U.) project to constrain dynamo models with realistic flows inferred from helioseismology. He is also working with C. Lindsey (NWRA) and others 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. Hill is working with other scientists at NWRA to develop a flare forecast based on vector magnetic field maps.

Future Research Plans

In addition to continuing studies of the evolution of large scale cycle-related flows, Hill plans to work with S. Tripathy and P. Cally (Monash U.) on correcting helioseismic phase shifts in the presence of inclined magnetic fields. These effects are large and corrupt the results of probing conditions below sunspots. The project will combine helioseismology, vector magnetometry and numerical simulations.

Service

Hill is the 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. Hill typically supervises several staff, currently eight scientists and two managers. He arranged annual operational support for GONG from the NOAA Space Weather Prediction Center (SWPC), was responsible for an NSF supplement to refurbish GONG, and is coordinating the relocation of the Tucson GONG engineering systems and the SOLIS instrument. 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 SPRING, a new network to obtain multi-wavelength observations for helioseismology, solar magnetometry, and space weather.

Sarah A. Jaeggli, Assistant Astronomer

Areas of Interest

The 3-dimensional structure of sunspot magnetic fields; atomic and molecular physics of the photosphere and chromosphere; radiative transfer modeling and spectral synthesis; instrumentation for spectroscopy and spectropolarimetry, including DKIST facility instrument development; engaging the community to perform multi-facility observations.

Recent Research Results

Dr. Jaeggli is close to publishing new ultraviolet identifications of molecular hydrogen based on radiative transfer and observations from the Interface Region Imaging Spectrograph, research conducted with P. Judge, A. Daw, and C. Jordan. She is currently investigatng the removal of instrumental polarization in high spatal resolution spectropolarimetry observations of sunspots from the Hinode/SOT-SP using ad-hoc techniques that may be critical for the characterization of polarization crosstalk from the DKIST primary and secondary mirrors.

Future Research Plans

Dr. Jaeggli hopes to use the DST to measure the height of the He I 1083nm magnetic field diagnostic in sunspot umbrae using umbral oscillations observed in the chromosphere. The phase lag between oscillations in He I and simultaneous observations of other diagnostics from other instruments and facilities should make it possible to determine the height. She also hopes to perform 3D radiative transfer calculations of a realistic sunspot atmosphere to synthesize solar diagnostics at the high spatial and spectral resolution that DKIST will be able to achieve.

Service

Dr. Jaeggli is supporting the DKIST project, acting as instrument scientist on the DL-NIRSP team, and as a member of the polarization calibration team.

Kiran Jain, Associate Scientist

Areas of Interest

Global and local helioseismology – solar cycle variation, multi-wavelength helioseismology, sub-surface dynamics, active region seismology; Sun-Earth connection.

Recent Research Results

Using the helioseismic data from GONG, Jain and co-workers investigated the progression of the solar cycle as observed in intermediate-degree global p-mode frequency shifts at different latitudes and subsurface layers, from the beginning of solar cycle 23 up to the maximum of the current solar cycle. The team's analysis highlighted differences in the progression of the cycle below 15° compared to higher latitudes. While the cycle starts at mid-latitudes and then migrates equatorward/poleward, the sunspot eruptions of the old cycle are still ongoing below 15° latitude. This prolonged activity causes a delay in the onset of the cycle and an overlap of successive cycles, whose extent differs in the two hemispheres. The activity level then rises faster, reaching a maximum characterized by a single-peak structure as opposed to the double peak at higher latitudes. Afterwards, the descending phase shows up with a slower decay rate. The latitudinal properties of the progression of the solar cycle highlighted in this study provide useful constraints for discerning among the multitude of solar dynamo models.

The high-cadence and high-spatial resolution Dopplergrams are often used to study subsurface dynamics in order to explore the precursors of visible solar activity on the surface. Since the p-mode power is absorbed in the regions of high magnetic field, the inferences in these regions are often presumed to have large uncertainties. Using the Dopplergrams from the space-borne Helioseismic Magnetic Imager, Jain compared horizontal flows in a shear layer below the surface and the photospheric layer in and around three active regions. The photospheric flows were calculated using the local correlation tracking method, while the ring-diagram technique of helioseismology was used to infer flows in the subphotospheric shear layer. A strong positive correlation between flows from both methods near the surface was found which implied that despite the absorption of acoustic power in the regions of strong magnetic field, the flows inferred from the helioseismology were comparable to those from the surface measurements. However, the magnitudes were significantly different; the flows from the LCT method were smaller by a factor of 2.

Future Research Plans

Jain will continue to study the changes in acoustic mode parameters with the changing level of magnetic activity in order to improve the understanding of their complex relationship. She will also continue to work on multi-spectral data to obtain a better picture of the excitation and damping mechanisms of solar oscillations. She further plans to extend the study of quasi-biennial periodicity in oscillation frequencies to different layers in the solar interior and different phases of the solar cycle to understand the physical mechanism responsible for various periodicities observed in oscillation data. She will also study the effect of inclined magnetic field on active regions to probe the characteristics of seismic waves propagating in layers above and below the solar surface. 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.

Service

Jain served as the Program Scientist of Interior Science Group of the NSO Integrated Synoptic Program (NISP) until May 2016 and continues to serve as a member of the Scientific Personnel Committee (SPC) of NSO. Jain has also served as the reviewer for research proposals submitted to NASA and research papers submitted to *Solar Physics*, *A&A*. She also served as a Guest Editor for the special issue of *Asian J. Physics* entitled "Solar Astronomy in 21st Century".

*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 to probe the deep layers of the sun.

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 using travel-time differences from velocity images reconstructed from SH coefficients after applying phase-velocity and low-L-filters. This particular approach is the key tool for extending the local time distance applications to the deep convection zone diagnostic analysis. The depth profile of meridional flow obtained using above described pipeline 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. Inversions of measured meridional travel-time differences showed single-cell structure of the meridional flow in both, depth and latitude.

Future Research Plans

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 and its temporal variations involving GONG, MDI and HMI data series. Also he will be involved on comparative analysis of simulated and observed solar oscillation data series.

Service

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

Rudolf W. Komm, Associate Scientist

Areas of Interest

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

Recent Research Results

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 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. He has focused on the divergence of horizontal flows and has derived (a) the relationship between the flow divergence patterns and magnetic activity, (b) the poleward branch of the divergence patterns, and (c) the divergence patterns during the extended minimum.

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.

Service

Komm is working on turning the measured helicity of subsurface flows into a data product. He continues to improve on a correction for systematic effects present in subsurface flow data. 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 search for flare-related changes in the solar interior as manifested in helioseismic "ring-diagrams", and various artifacts of ring-diagram analysis. An article on Kepler observations of solar oscillations in sunlight reflected by Neptune has been submitted for publication.

Future Research Plans

Leibacher and colleagues will shortly undertake the first stereoscopic helioseismology using the Kepler observations of Neptune and simultaneous observations from the Earth's neighborhood. In addition, a study of the physics of individual helioseismic modes' temporal variability (energy, phase) as a probe of their excitation and to fill gaps in the global-mode time series is getting renewed attention. These are based on a parametric analysis of the helioseismic time series, in contrast to the typical non-parametric analysis (Fourier transformation) followed by model fitting. A novel, horizontal phase-velocity and horizontal eigenfunction analysis of low-degree spherical harmonic mode frequencies to better probe the deep solar interior is being pursued.

Service

Dr. Leibacher serves as NSO Co-Diversity Advocate and member of the AURA Workforce and Diversity Committee, and provides scientific oversight of the *NSO Newsletter*. Leibacher has been a mentor to several undergraduate (REU) students and graduated students. He maintains the American Astronomical Society/Solar Physics Division *SolarNews* distribution and WWW site. He is a member of the Fachbeirat (scientific advisory committee) of the Max-Planck Society's Institute for Solar System Research (Göttingen), co-investigator/advisor to several external projects, and member of NASA's Heliophysics Subcommittee. He is editor-in-chief of the journal *Solar Physics*.

Jose Marino, Assistant Scientist

Areas of Interest

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

Recent Research Results

Jose Marino continues his involvement as a co-PI in a new NSF proposal to continue the joint project between NSO and the Big Bear Solar Observatory to develop a solar multi-conjugate adaptive optics system for the New Solar Telescope (NST), in Big Bear, CA. Marino participated in two successful engineering runs that took place at the NST in Big Bear in May and July 2016. Marino continues the development of a next generation adaptive optics simulation package that provides fast and accurate simulations of AO and MCAO systems. The simulation package was used to evaluate the performance of reconstruction algorithms to be used on the DKIST AO system. The latest results obtained with the AO simulation package were presented at the SPD meeting in Boulder, CO and the SPIE meeting in Edinburgh, Scotland, both during June 2016.

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 further our understanding of solar MCAO systems and conventional AO systems in large aperture telescopes, such as the DKIST. Marino will continue his involvement in the project to build a solar MCAO system at the Big Bear Solar Observatory. He will also continue to support the off-limb adaptive optics system that was developed by G. Taylor as part of his PhD thesis project, and explore its possible applications to the DKIST.

Service

During 2015 and 2016, Marino advised Elizabeth Carlisle during her internship at NSO. He continues to be involved in a graduate student project undertaken by CU-Boulder physics graduate student Courtney Peck. The project is supervised by Friedrich Wöger and Mark Rast. In October 2016, Marino gave a talk presenting his latest research results as part of the brown bag lunch-talk series at NSO in Boulder.

Matthew J. Penn, Astronomer

Areas of Interest

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

Recent Research Results

Penn has published the mid-IR flare observations in ApJ Letters, and the mid-IR spectropolarimetry observations at 4135nm in Solar Physics. Working with Tom Schad he has co-authored a paper currently accepted at ApJ involving Schad's spectropolarimetry of a cool coronal loop, and with the Citizen CATE Team has a fourth paper accepted for publication in PASP about the instrumentation development for CATE in 2015 and 2016. Penn and the CATE team are developing the follow-up science paper covering the coronal evolution observed from the 2016 Indonesian eclipse observations, and results will be presented at the Fall 2016 AGU meeting and submitted as an ApJ paper. Finally, the mid-IR flare ApJ Letters data is being analyzed by the University of Glasgow team to provide constraints on flare particle acceleration models, and will be submitted to ApJ for publication soon.

With data in-hand, Penn is collaborating with NASA/GSFC and Glasgow investigators to measure the solar diameter for the first time at 5, 10 and 13 microns. Infrared continuum observations of post-flare coronal loops taken in October 2015 are also being studied to measure flow speeds and the emission mechanism. In collaboration with NJIT/BBSO, Penn is working with graduate student Yang Xu on Ti I abundances, velocities and magnetic field measurements in a variety of sunspots, and with new CO 4666nm data taken with the CYRA instrument. Finally using a test camera Penn and NASA/GSFC colleagues took the first solar images of the limb and a sunspot at 20 microns at the McMath-Pierce solar facility.

Future Research Plans:

Collaborating with a team from MIT Lincoln Labs and NASA/JPL, Penn plans to test a fast mid-IR camera at the McMath-Pierce for use in the upcoming 2017 total solar eclipse. The only other plan for observations at the McM-P are to take 5,10 and 13 micron observations in support of the upcoming ALMA solar observations, in collaboration with several groups. CATE instrument development and volunteer training will be done in preparation for the 2017 eclipse.

Service

Following work from Lin & Penn (2004), Penn will be designing a modern version of a daily sky brightness monitor for DKIST. Application of the recent mid-IR flare, coronal loop and disk observations will be used to develop mid-IR science goals for the DKIST telescope, and to outline a potential new instrument. This recent research will be included in an update to the Infrared Soalr Physics 2014 Living Reviews article. Penn's work with students included being a research advisor to NJIT student Yang Xu, a research and summer mentor for groups of undergrads at Wyoming, Illinois, Kentucky and South Carolina, and the development of 20 high school and 21 university academic partners for the upcoming 2017 CATE experiment. Penn is on the AAS Eclipse Planning committee, and is working with NASA Heliophysics and the NASA Edge TV group for eclipse planning. Finally, Penn is also involved in developing an operations consortium for the McMath-Pierce solar facility.

Working with a team of instrumentalists from NASA/GSFC and a team from RHESSI, Dr. Penn has submitted a paper with a preliminary interpretation of the infrared continuum emission observed in a C7 flare from 2014. Combining 5 and 8 micron data from the McMath-Pierce solar facility with visible observations from SDO/HMI and x-ray data from RHESSI, the paper concludes that the IR emission is likely optically thin and comes from a region with a density less than about 3×10^{13} cm^{-3}, probably from free-free emission. The paper will appear in *ApJ Letters*. Working with another group, Penn is currently revising a paper submitted to Solar Physics concerning spectropolarimetric observations at 4135 nm of Fe I, Si I, and molecular photospheric absorption lines. Several strongly split lines are measured, including a weak line which shows the largest quiet Sun magnetic splitting ever observed. Finally, with colleagues from U Wyoming, Southern Illinois University Carbondale, Western Kentucky University and South Carolina State University and funding from NASA/SMD, Penn is organizing a five-site observing run during the March 2016 Indonesian total solar eclipse, in order to study the radial velocity, and quasi-periodic density enhancements seen in polar plumes in the solar corona from 1.0 to 2.0 solar radii.

Future Research Plans

With NASA/GSFC, Penn is developing two longer wavelength imaging instruments for solar work at the McMath-Pierce, including a 13-micron QWIP detector aimed at studying flares, and a new strained-layer superlattice (SLS) 1K x 1K detector for solar imaging from 2 to 14 microns. Applications of these devices to DKIST and as a complement to longer wavelength observations from ALMA will be explored in an NSO workshop in March 2016. Using CO 4666 nm observations taken during a partial eclipse in 2012, and Mn I 1523 nm observations from an eclipse in 2014 (both at Kitt Peak), Penn will explore the height of molecular formation and the magnetic field strength in the upper solar photosphere. Finally, Penn is working on a 60-site observing network for the upcoming 2017 solar eclipse involving corporate sponsors and citizen scientists.

Service

Dr. Penn is establishing partners for the McMP Operations Consortium, which will take over operations of the facility in 2017. He 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 was collected in 2015 showing Ti I 2233 nm absorption in several sunspot umbrae. Penn is a research advisor for NJIT graduate student Xu Yang. He is in charge of the NSO summer Research

Experiences for Undergraduates (REU) and has hired undergraduates from the University of Arizona to work on an eclipse experiment. Penn has joined the AAS 2017 Eclipse task force. He is working with a group from Northrop-Grumman to conduct tests on the use of Starshades for exo-planet imaging at McM/P.

Gordon J. D. Petrie, Associate Scientist

Areas of Interest

Solar magnetic fields

Recent Research Results

Petrie investigated the possible use of high-resolution vector magnetic field measurements for the Sun's polar fields in synoptic magnetograms and global coronal and heliospheric modeling. Global coronal field models are particularly sensitive to polar field data, but existing full-disk vector magnetograms from SOLIS/VSM and SDO/HMI lack the spatial resolution and sensitivity to resolve the facular-scale magnetic structure that dominates the polar fields, especially taking foreshortening into account. The NSO's DKIST vector magnetographs will likely provide the most sensitive, highest-resolution polar scans but, until DKIST begins operating, Petrie used Hinode/SOT-SP polar vector magnetograms in combination with SOLIS/VSM data for the remainder of the solar surface, to develop possible improvements to synoptic maps and global field models. A paper has been accepted by *Solar Physics*.

Petrie completed and published his paper on two major X-class flares from 2011, observed by the HMI vector magnetograph and AIA extreme ultraviolet (EUV) imager on SDO, as well as the STEREO A/EUVI telescope from a viewpoint ~90° separated from Earth. He found that the differences between the flare related changes in the photospheric magnetic and Lorentz force vector fields corresponded to the EUV collapsing loop structure changes as observed from the SDO and STEREO viewpoints. The photospheric patterns are similarr for the two flates but the coronal patterns are very different, conforming to two distinct flare models: the tether-cutting and breakout models. This work has been published as *Solar Physics,* 291, 791.

Petrie wrote an article with his 2015 REU student Stella Ocker (Oberlin College) on a study of the effects of atmospheric seeing and smoothing on magnetic helicity calculations. Using Hinode/SOT-ST vector magnetograms for 179 active regions, they compared helicity parameter distributions with and without the smoothing effects of atmospheric seeing and found that contradictory results found by previous authors were unlikely to be due to atmospheric seeing effects. Focusing on two contrasting active regions they found major differences in helicity parameter distributions between smoothed and unsmoothed data, but overall statistics did not significantly changed. Discrepancies between past studies were likely caused by sampling differences and solar cycle variations. This article is in press with the Astrophysical Journal.

Service

Petrie analyzed the zero-point error in the GONG magnetograms, which are heavily used by space weather scientists at NASA, NOAA, AFRL and elsewhere. Having previously demonstrated that a part of the existing correction algorithm has been unintentionally erasing real solar fields that are weak but have large spatial scales, he worked with NISP programmers to fix the problem by identify real weak, large-scale gradients in the fields via inter-comparison of images from across the GONG network, and to preserve these signals in the final magnetograms while eliminating artifacts. This algorithm is being finalized.

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 journals including the *The Astrophysical Journal*, *Astronomy and Astrophysics*, *Solar Physics, Physics Frontiers, Nature Communications* and the *Journal of Geophysical Research*. Petrie mentored REU student Tyler McMaken (Case Western Reserve University) during summer 2016, studying the effects of supergranular diffusion on the giant active region NOAA 12192, focusing on helicity transport, the related formation of a major filament, and the impact on the Sun's polar field. We plan to write a journal article next year.

Alexei A. Pevtsov, Astronomer

Areas of Interest

Solar magnetic fields: topology, evolution, helicity, vector polarimetry; corona: coronal heating, x-ray 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, space climate.

Recent Research Results

A. Pevtsov employed historical data sets (CaK spectroheliograms and sunspot field strength measurements) in attempt to create a set of pseudo-magnetograms over the period of more than 100 years. Spectroheliograms were used to create maps of unsigned magnetic flux, and visual measurements of sunspot magnetic field strengths were employed to assigned polarity to those flux elements. Pseudo-magnetograms created that way showed significant agreement in sign of magnetic flux elements with actual magnetograms for common period of observations. In other research project, in collaboration with NSO and non-NSO colleagues Pevtsov evaluated the benefits of having additional magnetographic instrument at Lagrangian L5 point on modeling of solar wind parameters at Earth. Using near-real-time synoptic magnetograms from VSM/SOLIS, they created two data sets: one data set excluded magnetic field of two isolated active regions from L1 viewing angle, and the other included these data as a combination of L1 and L5 field of views. The datasets were used as input for WSA-ENLIL model. The comparison of two modeling outcomes indicates that without L5 input, the difference in predicted solar wind speed may reach about 30%, in electron density up to 70%, 20-25% in magnetic field strength and 45-50% in temperature. In a separate study, modeling of coronal fields using magnetofriction model indicates that the effects of missing active regions from L5 magnetograms may persist even after the magnetic flux enters the L1 field of view. In addition to research in solar physics, A. Pevtsov participated in several studies in solar-stellar research. The goal of these studies was to determine correct S-index for solar Ca II K sun-as-a-star observations to enable comparison with other sun-like stars.

Future Research Plans

Dr. Pevtsov will continue his research on properties and evolution of magnetic fields on the Sun. As a long-term goal, this research aims at understanding how magnetic fields are created by the global and local dynamos, and how the magnetic field evolves and decays. He will also continue research aimed at better characterization of benefits of instrument at L5 point for space weather forecast, and his sun-as-a-star studies. He also plans expanding solar-stellar component of his research.

Service

A. Pevtsov was the Solar Atmosphere Program Scientist for the NSO Integrated Synoptic Program (NISP), and he served on the Math and Science Advisory Council (MSAC) for New Mexico State's Public Education Department This activity had ended with Pevtsov taking a one year sabbatical leave. He continues chairing the NSO's Scientific Personnel Committee (SPC). Pevtsov reviewed proposals for NASA and NSF, served as a reviewer for several professional publications, and supervised one Summer Research Assistant at NSO/SP. He serves on the Users' Committee for HAO's Mauna Loa Solar Observatory and the Advisory Board for the Historical Archive of Sunspot Observations (HASO) at the University of Extremadura (Spain). He is the co-chair for the International Astronomical Union (IAU) Inter-Division B-E Working Group on Coordination of Synoptic Observations of the Sun, and the lead for magnetographs and imagers group for future L5 mission.

Valentín Martínez Pillet, NSO Director

Areas of Interest

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

Author of 103 refereed papers, 204 NASA/ADS entries, 3555 citations, H-index 34.

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).

Future Research Plans

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 rejuvenate the NSO synoptic program, and prepare for observatory operations at the new NSO directorate site in Boulder, Colorado. Dr. Pillet plans to be involved 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.

With an REU student, Dr. Pillet is developing alternative ways to calibrate the instrumental polarization of DKIST with an approach that is complementary to the one that would be regularly done at the facility.

Service

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.

Kevin Reardon, NSO Data Center Scientist

Areas of Interest

Dynamics and structure of the solar chromosphere, transition region, and corona; 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; history of solar astronomy.

Recent Research Results

K. Reardon has continued some efforts to study the small-scale dynamics of the solar atmosphere. He participated in an International Space Science Group (ISSI) workshop on "Sub-arcsecond Observations and Interpretation of the Solar Chromosphere." He is also a team member for a new ISSI group to study solar UV bursts in order to understand their underlying magnetic drivers. He has also worked with Rob Rutten and Alfred de Wijn on study the temperature and density structure of the chromosphere by using high-resolution observations of the He I D3 line.

Dr. Reardon has collaborated with several groups on NASA Heliophysics Guest Investigator proposals. He was a Collaborator on a successful H-GI proposal led by Peter Young of George Mason University to study small-scale energy supply and release in compact energetic brightenings near active regions. He was also Collaborator or Co-Investigator on two other proposals in a later round of funding.

He has worked with Lucia Kleint and collaborators on evaluating the data from the March 29 2014 X1.0 flare observed at the Dunn Solar Telescope with IBIS , ROSA, and FIRS. The IBIS data show the polarimetric signature of the changes in the magnetic field after the energy release and restructuring caused by the flare and filament eruption.

Future Research Plans

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, compressing, and classifying the contents of those data, as well as data distribution channels, including the Virtual Solar Observatory, that support data discovery and visualization by the community.

Reardon will continue to work with Philip Judge, Rob Rutten, 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. He will work with Peter Young and the ISSI group to understand small-scale brightenings in the low solar chromosphere. He will work on analyzing IBIS data taken during the EUNIS, VAULT, and CLASP rocket flights.

K. Reardon is also working with Fabio Cavallini and Vincenzo Greco (INAF/Arcetri) to develop and test large aperture (150mm) Fabry-Perot interferometers which would be suitable for applications on DKIST. The prototype is under production by Queengate and is expected to be delivered in early 2016. Reardon will help in the analysis of the measurements to characterize the plate separation errors of this new design.

K. Reardon also plans to observe the transit of Mercury from the Dunn Solar Telescope in May, 2016, in order to get new measurements of the temperature and density profiles of Mercury's exosphere at the terminator, as well as evaluating the scales of unresolved structures of the solar atmosphere.

Service

As the NSO Data Center Scientist, Reardon is engaging the community in order to elicit their needs and approaches for processing and archiving of the data from the DKIST. He is also providing leadership in the implementation of a modern data center deploying advanced analysis techniques in support of NSO's mission.

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, VERIS, VAULT and CLASP sounding rocket launches from NASA's White Sands Missile Range.

He continues to provide images and information that is used in NSO's EPO outreach efforts. He serves as a referee to the *Astrophysical Journal*.

Thomas R. Rimmele, Astronomer

Areas of Interest

Sunspots; small-scale magnetic surface 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, Dr. Rimmele's time is fully committed to the extensive management, organizational and service tasks. Rimmele, however, maintains a strong interest in the development of AO technology. He is supervising and mentoring DKIST Postdoctoral Fellow Dirk Schmidt and NSO Assistant Scientist Jose Marino. Both are working on developing multi-conjugate adaptive optics for the Sun in collaboration with BBSO and Kiepenheuer Institute in Gemany. In 2014, Rimmele co-authored seven 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.

Service

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.

Thomas A. Schad, Assistant Astronomer

Areas of Interest

Chromospheric and coronal magnetic field dynamics; precision spectropolarimetry; infrared instrumentation, including DKIST facility instrument development; student engagement and community outreach.

Recent Research Results

T. Schad's work to measure the resolved height variation of the coronal magnetic field above a sunspot has recently been accepted by The Astrophysical Journal. Using a unique combination of space-based stereoscopic measurements and ground-based polarimetry from the Dunn Solar Telescope, T. Schad was able, for the first time, to reconstruct the full 3D topology and 3D vector magnetic field of a coronal loop. This work advances new remote sensing methods while also providing necessary constraints on the scale height of active region coronal magnetic fields.

Future Research Plans

Dr. Schad continues to pursue new techniques for inferring the magnetic field structure of upper atmospheric dynamics including the chromosphere and cool corona, including the advancement of prototype instrument concepts as existing facilities. He is currently investigating preliminary results from a 17-slit massively multiplexed slit spectrograph used for dynamic spectroscopic imaging in the infrared. He is also engaging partners to conduct in polarimetry of the hot corona, as well as eruptive solar filaments.

Service

Schad is an active member of the DKIST Science Group, the scientific lead for the DKIST Instrument Control System, and infrared instrumentation specialist for the facility instrument development and polarimetric calibration and analysis teams. Schad also conducts educational outreach for the local Maui community. In 2016, he orchestrated island wide outreach events, including a local art contest, around the partial solar eclipse of March 2016.

Dirk Schmidt, DKIST Postdoctoral Fellow

Areas of Interest

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 & 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 „Clear", which is a pathfinder for a DKIST MCAO system. Clear has provided the first ever clearly visible improvement to image quality with MCAO correction compared to classical adaptive optics correction in summer 2016. Clear has also been used to explore ground-layer adaptive optics (GLAO) for solar observations in 2016. Following up on the demonstrations of the potential of MCAO and GLAO, Schmidt will dedicate his efforts to make these new AO techniques robust and ready for scientific observations of the Sun, and to upgrade the DKIST with advanced wide‐field AO systems.

Sushanta C. Tripathy, Associate Scientist

Areas of Interest

Magnetoseismology of active regions; global and local helioseismology; solar activity cycle; ring-diagram analysis, sub-surface flows

Recent Research Results

S. Tripathy has investigated the interaction between acoustic waves and magnetic field at different heights in the solar atmosphere in order to comprehend the interaction between the two. As a first step, using data from AIA and HMI on board Solar Dynamics Observatory, Tripathy has studied the spatio-temporal power distribution in and around active regions as a function of wave frequencies, magnetic field strength, and field inclination and observation height. It is found that the spatial extent of power halos and the frequency extent increase with height is consistent with expanding field lines and hence upward rising of the layer where the Alfven velocity equals the sound speed.

Dr. Tripathy has continued the investigation of variations of the high degree mode frequencies. Analyzing the frequency shifts obtained from Global Oscillation Network Group, it was found that the conditions below the sub-surface layers were different between the cycles 23 and 24. It was also found that the minimum phase between cycles 23 and 24 lasted only for about 16 months while the solar activity indices lasted for a period of about 30 months suggesting a weaker relationship between the frequency shifts and solar activity during the unusually long solar minimum.

Dr. Tripathy was invited by the Editor of Asian Journal of Physics to compile a special issue as well as to write a review article summarizing the results from solar cycle prediction methods. In this article, various methods were outlined and the predicted results were compared starting from cycle 21 but with importance given to those from cycle 24. Further, predictions for cycle 25 and beyond were reviewed.

Future Research Plans

Using data from AIA and HMI for multi-wavelength seismology, Tripathy will further study the wave interaction between the active region and magnetic field by analyzing the phase and coherence as a function of the height. It is also planned to compare the observational results with those from the numerical simulations. Dr. Tripathy intends to extend the analysis of quasi-biennial periodicity seen in the global oscillation mode frequencies to other mode parameters e.g., line widths and amplitudes to understand the mechanism that drives this additional periodicity. Tripathy also proposes to compare the high-degree oscillation frequencies between cycles 23 and 24 to comprehend the changes near the sub-surface shear layer.

Service
S. Tripathy organizes the weekly interior science meeting at NSO. Recently, he has taken over the role of science lead for the interior group. In recent past, he has been a reviewer for scientific journals as well as research proposals from NASA.

Alexandra Tritschler, Associate Scientist

Areas of Interest
Operations of large astronomical facilities; operations tools used by the users and operators of such facilities; high-resolution spectroscopy and spectropolarimetry of the photosphere and chromosphere of active regions; solar magnetic fields; fine-structure of sunspots; numerical simulations of magneto-convection in (and around) sunspots and using those as input for spectral synthesis; post-focus instrumentation.

Current and Future Research Plans
Dr. Tritschler’s main interests will continue to be focused on the operations of astronomical facilities and the high-resolution aspects of the photospheric and the chromospheric atmospheric layers of solar active regions. She will further explore the operational modes and tools used by astronomical communities for the development of DKIST Operations. She will continue to employ ground-based high-resolution spectroscopic and spectropolarimetric observations 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.

Service
Tritschler is the DKIST's Operations Scientist and as such guides the development of DKIST Operations. She is responsible for the development and specification of all operations tools to be used to efficiently operate the DKIST. Tritschler leads the Service Mode Operations effort of the Dunn Solar Telescope in preparation for DKIST Operations. Originally part of the transition plan of the NSO, Service Mode Operations of the DST, however, are no longer offered. 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 actively involved in the organization of international as well as DKIST workshops (as a SOC member). Tritschler has served on NSO hiring committees, 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

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

Recent Research Results
H. Uitenbroek continues to work on expanding and improving his multi-dimensional numerical radiative transfer code 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 are now widely sited in IRIS based papers. 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. 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 RH code was also used to investigate the role of uncertainty in atmospheric models for inferring magnetic fields in the chromosphere with the Hanle effect in the Lyman-alpha line in support of the CLASP sounding rocket flight. The code is being used by de la Cruz Rodriguez and collaborators as the forward engine in a new Non-LTE spectral line inversion code, and serves as the main ingredient in a massively parallel 3-D transfer code created by Perreira.

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.

Service

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). He actively supports users of the RH code with updates and helps with running the code. His 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, and serves on the Science Team for DKIST.

Friedrich Wöger, Associate Scientist

Areas of Interest

Image reconstruction techniques; adaptive optics; two-dimensional spectroscopy, and spectro-polarimetry; DKIST instrumentation, in particular the visible broadband imager (VBI); DKIST wavefront correction system (WFC); DKIST data handling system (DHS).

Recent Research Results

F. Wöger is studying the sensitivity of analytical models for optical transfer functions used by speckle interferometry algorithms to input parameters in collboration with a CU graduate student. This work will provide the foundation for the characterization of the photometric precision in images reconstructed by the VBI.

Wöger is continuing to guide and aid the construction and testing of DKIST subsystem components, such as e.g. VBI optical components and development of user acceptance tests.

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.

Service

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 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 on DKIST instrumentation over the course of 2016 to further community interest in the DKIST project.

APPENDIX I. ACRONYM GLOSSARY

A&E	Architecture and Engineering
AAG	Astronomy and Astrophysics Research Grants (NSF)
AAS	American Astronomical Society
ADAPT	Air Force Data Assimilative Photospheric flux Transport
AD	Associate Director (NSO)
AFRL	Air Force Research Laboratory
AFWA	Air Force Weather Agency
AGS	Atmospheric and Geospace Sciences Division (NSF)
AGU	American Geophysical Union
AIA	Atmospheric Imaging Assembly (SDO)
AISES	American Indian Science and Engineering Society
aO	Active Optics
AO	Adaptive Optics
APRPP	Annual Progress Report and Program Plan (NSF)
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
AU	Astronomical Unit
AURA	Association of Universities for Research in Astronomy, Inc.
AWI	Akamai Workforce Initiative (Hawai‘i)
BABO	Baboquivari Instrument (NSO McMath-Pierce Solar Telescope)
BLNR	Bureau of Land and Natural Resources
BBSO	Big Bear Solar Observatory
BOE	Basis of Estimate
BSA	Boulder Solar Alliance
CA	Cooperative Agreement
CAS	Central Administrative Services (AURA)
CATE	Citizen Continental America Telescopic Eclipse
CAM	Cost Account Manager (DKIST)
CCD	Charge Coupled Device
CCMC	Community Coordinated Modeling Center
CDAW	Coordinated Data Analysis Workshop (
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
COLLAGE	COLLAborative Graduate Education (University of Colorado, Boulder)
COS	College of Optical Sciences (University of Arizona)
CoRoT	COnvection ROtation and planetary Transits (French Space Agency CNES)
CoSEC	Collaborative Sun-Earth Connection
CR	Carrington Rotation
Cryo-NIRSP	Cryogenic Near-IR Spectropolarimeter (DKIST)
CSA	Cooperative Support Agreement
CSF	Common Services Framework
CSIC	Consejo Superior de Investigaciones Cientificas (Spain)
CSP	Critical Science Plan
CU Boulder	University of Colorado, Boulder
CYRA	Cryogenic Infrared Spectrograph (NJIT, Big Bear Solar Observatory)
DA	Diversity Advocate
DAS	Data Acquisition System
DB-P	Dual-beam Polarizer (McMath-Pierce Telescope)
DC	Data Center
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 Spectropolarimeter
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
EA	Environmental Assessment
EAST	European Association for Solar Telescopes
EGSO	European Grid of Solar Observations
EGU	European Geosciences Union
EIS	Environmental Impact Statement
EIT	Extreme ultraviolet Imaging Telescope (SOHO)
EPO	Educational and Public Outreach
ESA	European Space Agency

ESF	Evans Solar Facility
EST	European Solar Telescope
ETS	Engineering and Technical Services (NOAO)
EUV	Extreme Ultraviolet
FAT	Factory Acceptance Testing
FDP	Full-Disk Patrol (SOLIS)
FDR	Final Design Review
FEIS	Final Environmental Impact Statement
FIRS	Facility Infrared Spectropolarimeter
FMS	Flexible Manufacturing System
FLC	Ferroelectric Liquid Crystal
FOCS	Feed Optics Control Software
FOV	Field of View
FPGA	Field Programmable Gate Array
FTEs	Full Time Equivalents
FTS	Facility Thermal Systems (DKIST)
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
HIDEE	Heliophysics Infrastructure and Data Environment Enhancements (NASA)
HMI	Helioseismic and Magnetic Imager
HO	Haleakalā Observatory
HOAO	High Order Adaptive Optics
HQ	Headquarters
HR	Human Resources
HSG	Horizontal Spectrograph
HXR	Hard X-Ray
IAA	Instituto de Astrofísica de Andalucía (Spain)
IAC	Instituto de Astrofísica de Canarias (Spain)
IAU	International Astronomical Union
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)

IMF	Interplanetary Mean Field
INAF	Istituto Nazionale di Astrofisica (National Institute for Astrophysics, Italy)
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
JPL	Jet Propulsion Laboratory (NASA)
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)
LASCO	Large Angle and Spectrometric Coronagraph (NASA/ESA SOHO)
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
MHD	Magnetohydrodynamic
MKIR	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)
MSIP	Mid-Scale Instrumentation Program (NSF)
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)
NSTC	National Science Technology Council
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
OEO	Office of Education and Outreach (NSO)
OFCM	Office of the Federal Coordinator for Meteorology
OMB	Office of Management and Budget
O-SPAN	Optical Solar Patrol Network (formerly ISOON)
PAARE	Partnerships in Astronomy & Astrophysics Research & Education (NSF)
PA&C	Polarization Analysis & Calibration
PAEO	Public Affairs and Educational Outreach (NOAO)
PCA	Principal Component Analysis
PDR	Preliminary Design Review
PI	Principal Investigator
PM	Project (or Program) Manager (NSO)
PMCS	Project Management Control System
PRD	Partial Frequency Redistribution
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)
QWIP	Quantum Well Infrared Photodetector
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
ROB	Remote Office Building
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
SREC	Southern Rockies Education Centers
SSEB	Source Selection Evaluation Board (Federal Government)

SSL	Space Sciences Laboratory (UC Berkeley)
SSP	Source Selection Plan (DKIST)
SST	Swedish Solar Telescope
STEREO	Solar TErrestrial RElations Observatory (NASA Mission)
SW	Solar Wind
SSWG	Site Survey Working Group (DKIST)
SWG	Science Working Group (DKIST)
SWMF	Space Weather Modeling Framework
SWORM	Space Weather Operations, Research and Mitigation (NTSC)
SWPC	Space Weather Prediction Center (NOAA)
SWRI	Southwest Research Institute
STARA	Sunspot Tracking and Recognition Algorithm
STEM	Science, Technology, Engineering and Mathematics
STEP	Summer Teacher Enrichment Program
SUMI	Solar Ultraviolet Magnetograph Investigation (NASA, MSFC)
SUP	Special Use Permit
SWPC	Space Weather Prediction Center (NOAA)
TAC	Telescope Time Allocation Committee
TB	Tera Bytes
TCS	Telescope Control System
TEOA	Top End Optical Assembly (DKIST)
TLRBSE	Teacher Leaders in Research Based Science Education
TMA	Telescope Mount Assembly
TIMED/SEE	Thermosphere Ionosphere Mesosphere Energetics and Dynamics / Solar EUV Experiment (NASA)
TRACE	Transition Region and Coronal Explorer
UA	University of Arizona
UH	University of Hawai‘i
UBF	Universal Birefringent Filter
UK	United Kingdom
UPS	Uninterruptible Power Supply
USAF	United States Air Force
USF&WS	US Fish and Wildlife Service
VBI	Visible-light Broadband Imager (DKIST)
VCCS	Virtual Camera Control System (Dunn Solar Telescope)
VFD	Variable Frequency Drive
VFISV	Very Fast Inversion of the Stokes Vector (Inversion Code, HMI)
ViSP	Visible Spectropolarimeter (DKIST)
VSM	Vector SpectroMagnetograph (SOLIS)
VSO	Virtual Solar Observatory
VTF	Visible Tunable Filter (DKIST)
VTT	Vacuum Tower Telescope (Tenerife, Spain)
WBS	Work Breakdown Structure
WCCS	Wavefront Correction Control System
WDC	Workforce and Diversity Committee (AURA)

WFC	Wavefront Correction (DKIST)
WHI	Whole Heliospheric Interval
WSA	Wang-Sheeley-Arge (Solar Wind Model)
WSDL	Web Service Description Language
WWW	World Wide Web