From the NSO Director's Office

Steve Keil

The National Astronomy and Astrophysics Advisory Committee (NAAAC)—recently formed to advise NASA and the National Science Foundation (NSF) on opportunities for joint projects—offers an opportunity to coordinate the major funding agencies of astronomy and space science. This should impact how well the top-rated projects within either agency will fare, and how rapidly they progress. The committee charge should now prevent the work of the decadal panels from being relegated to a back seat for another set of priorities. As development of both the Solar Dynamics Observatory (SDO) and Advanced Technology Solar Telescope (ATST) progresses with the strong support of the solar community, a plan needs to be developed for using NAAAC advice and support to achieve the tremendous science potential of these two facilities. This is a significant opportunity, and I welcome community input on possible ways to proceed. Please contact me by telephone at 505-434-7039, or by e-mail at *skeil@nso.edu*.

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Be sure to visit our ATST Web site for an update on some of the exciting concepts that are being explored (see the following ATST article). Since the fall 2002 workshop (which placed a strong emphasis on evaluating domes) several new concepts for potential solar domes have emerged. The engineering and science teams are hard at work measuring the properties of existing domes that range from the latest in ventilated technologies on Gemini to more classic designs like the Big Bear Solar Observatory dome. We are also investigating collapsible dome designs like those used on the Dutch Open Telescope on La Palma and the Air Force Maui Space Surveillance System (MSSS) on Haleakala. These evaluations require a lot of work and forethought. For example, one issue with collapsible domes is the control of wind flow across the mirror once the dome is collapsed.

The overall concepts for the telescope are being developed with the aim of having a conceptual design review in August. Estimates for the overall cost are also being refined. Currently, we estimate that the ATST will cost around $120 million in 2003 dollars. This estimate includes three major instruments, integrated adaptive optics (with an upgrade path for multiconjugate adaptive optics), and support facilities for operations, and also allows for continued instrument renewal and mirror maintenance.

What does the ATST mean for the National Solar Observatory? It will introduce a totally new era of solar physics and, combined with other national assets such as SOLIS and GONG, it will produce prodigious amounts of data that will be fully accessible to the solar community. This may lead to modifications of the principal investigator (PI) mode on existing national telescopes like the Dunn and the McMath-Pierce Solar Telescopes. Under our current operations, the PI typically takes very "raw" data home, processes it for a few years, and then publishes. The data are not archived. We will have to consider whether it is better to continue to give the PI exclusive use or whether all PI data should become available after a specified period of time. Of course, the synoptic data will continue to be in the public domain and linked with a virtual solar observatory. These are significant issues and, again, I would appreciate your input.

With the advent of the ATST, NSO will need to restructure its program to efficiently operate not only the ATST but other national solar assets as well. One change we are considering is the consolidation of scientific staff to a single headquarters location. A possible scenario for this consolidation is to locate NSO headquarters at or near a university that has a strong interest in developing or strengthening its solar physics program. We would like to hear from scientists at universities that might be interested in exploring such a synergistic relationship.

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Thanks to the hard work and creative efforts of Ruth Kneale, NSO now has a remodeled Web site (*www.nso.edu*) with an attractive and more user-friendly format. Thank you, Ruth! In other news on the digital front, the NSO Digital Library is brimming with activity, and is preparing for the impact of both GONG mega-plus and SOLIS data. Fortunately, NSO will soon receive funding from NASA/GSFC to oversee the construction of the Virtual Solar Observatory (VSO), which eventually will make access to synoptic and other data much easier. The VSO effort will cover two years, and will be in collaboration with Stanford University, Montana State University, and the Solar Data Analysis Center (SDAC) at NASA/GSFC. As of now, an operational skeleton that uses the core technologies for the system already exists but is not yet connected to the archives. In the current work schedule, a prototype VSO linking the NSO Digital Library (including SOLIS and GONG), the Stanford SOI archive, the MSU Yohkoh archive, and the SDAC (including SOHO, SMM, etc.) will be operational in fall 2003. The system will be tested, debugged, and expanded over the following 18 months, and will be generally available in spring 2005.

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NSO Director's Office continued

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Speaking of GONG, GONG++ is now producing high-spatial-resolution oscillation data. The GONG section in this *Newsletter* describes the project's latest changes and streamlining efforts. GONG also just received a NASA grant to further the development of farside imaging for Space Weather and to help make real-time data available.

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If you haven't been a user of NSO facilities lately, now is the time to kick old habits and take advantage of the "rebirth" of our facilities. Adaptive optics and diffraction-limited instruments in the visible and infrared (IR) are providing the opportunity to make breakthrough observations. You can now witness, for example, a flux tube collapsing, a spicule jet, or the birth and propagation of waves along flux tubes. NSO will provide support to obtain your data and help with getting the proper tools to analyze it. If you are interested in observing at the NSO, visit the NSO Web site and click on "Observing at NSO."

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The NSO staff continues to rack up outstanding personal achievements, some of which have been recently recognized with awards. In recognition of his record of outstanding work for GONG, and more recently the ATST site survey, as well as for his excellent scientific productivity, Frank Hill was promoted to Senior Scientist. Congratulations to Frank for doing an outstanding job on everything he does. Craig Gullixson was presented with the 2003 AURA technical achievement award for his work on Fabry-Perot etalons, which enabled the new US Air Force Improved Solar Observing Optical Network (ISOON) telescope to produce stunning images in Hα and white light, as well as to make magnetograms. If you haven't seen the images yet, be sure to check them out on the NSO Web site. Cliff Toner received this year's AURA service award. Cliff developed, implemented, and continues to refine the merging of the individual GONG sites' data to make the network a single instrument. Without this, there would be six links but not a chain, and none of the GONG science would be possible. Cliff's strong support of the helioseismology community has been outstanding. The AURA science award this year went to Christoph Keller in recognition of his scientific and technological leadership in the development of an innovative adaptive optics system for IR observations at the McMath-Pierce Telescope Facility. Christoph, with Claude Plymate's excellent assistance, developed a low-cost adaptive optics system for solar observations in the IR between 1 and 28 microns with the 1.5-meter McMath-Pierce Solar Telescope.

And last, but certainly not least, the Solar Physics Division (SPD) of the American Astronomical Society (AAS) has awarded its 2003 Hale Prize to NSO emeritus Bob Howard "for his pioneering discoveries of fundamental properties of solar magnetic and velocity fields; initiating modern instrumentation and archiving methods for long-term solar observations; and selfless mentoring, collaboration, and leadership of solar physics research programs and institutions." After many years leading the solar program on Mt. Wilson, Bob joined NSO in the mid-80s as its founding director. Bob's Hale Prize lecture will be given at the SPD meeting in Laurel, MD, this June, after the formal presentation at the AAS meeting in Nashville. Congratulations to Bob on this well-deserved honor.

2003 AURA Award Recipients with NSO Director Steve Keil (left to right): Craig Gullixon, AURA Technical Achievement Award; Cliff Toner, AURA Service Award; Christoph Keller, AURA Science Award.

The High-Order Solar Adaptive Optics Project Achieves Major Milestones

The Adaptive Optics Team

Impressive, sharp images of the Sun can be produced with an advanced adaptive optics (AO) system that also helps open the way for large-aperture solar telescopes. This engineering advance was achieved in late 2002 and April 2003 by an NSO team at Sunspot, NM.

Since August 2000, the NSO, in primary partnership with the New Jersey Institute of Technology (NJIT), has been developing high-order solar AO for use at the 65-centimeter telescope at Big Bear Solar Observatory (BBSO), and the 76-centimeter Dunn Solar Telescope (DST) at Sacramento Peak. The National Science Foundation (NSF) has sponsored this project within the Major Research Instrumentation program with substantial matching funds from the participating partner organizations, which include the NSO, the NJIT, the Kiepenheuer Institute in Germany, and the Air Force Research Laboratory. The high-order AO system will upgrade each of these high-resolution solar telescopes and greatly improve their scientific output. The resulting systems will also serve as proofs-of-concept for a scalable AO design for the much larger 4-meter Advanced Technology Solar Telescope (ATST). Compared to the low-order AO system currently operating at the DST, the high-order AO system provides a threefold increase in the number of deformable mirror actuators that are actively controlled.

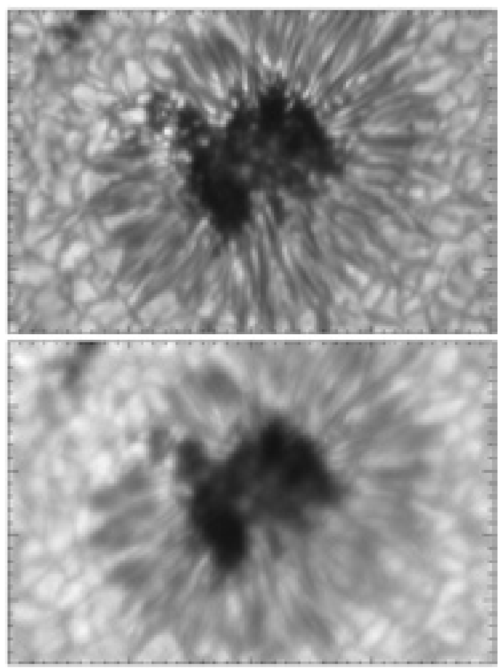

Figure 1. Corrected (top) and uncorrected (bottom) images of a sunspot. The uncorrected image is tip-tilt stabilized. The exposure time is 200 milliseconds, the wavelength is 500 nanometers, and the tick marks are 0.5 arcsec.

Starting in December 2002, the high-order solar AO team achieved several major milestones. First, during the first engineering run at the DST, the servo loop was successfully closed on the new high-order AO system for the first time. At this point the system used a DALSA camera, which operates at 955 frames per second, as the interim wavefront sensor. The optical setup was not finalized and preliminary, "bare-bones" software operated the system.

The goal of these tests was to demonstrate that all the components work together as a system. Even in this preliminary state, the AO system delivered images with impressive quality. Figure 1 demonstrates that even in mediocre seeing conditions, diffraction-limited imaging can be provided by the high-order AO system. Time sequences of corrected and uncorrected images show that the new AO system provides fairly consistent high-resolution imaging even as the seeing varies substantially, as is typical for daytime conditions.

In April 2003, the high-order AO system was turned on for the first time with the new high-speed wavefront sensor camera. This camera is based on a CMOS device and operates at 2,500 frames per second, which more than doubles the closed-loop servo bandwidth of the system compared to the DALSA camera. The camera was custom developed for the AO project by BAJA Technologies and the lead AO project engineer, Kit Richards of NSO. Richards also implemented improved control software for the April engineering run.

"If the first results were impressive, I would call the performance that we are getting now truly amazing," said Thomas Rimmele, the Principle of the AO project. "I'm quite thrilled with the image quality delivered by this new system. I believe it's fair to say that the images we are getting are the best ever produced by the Dunn Solar Telescope."

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High-Order Solar Adaptive Optics continued

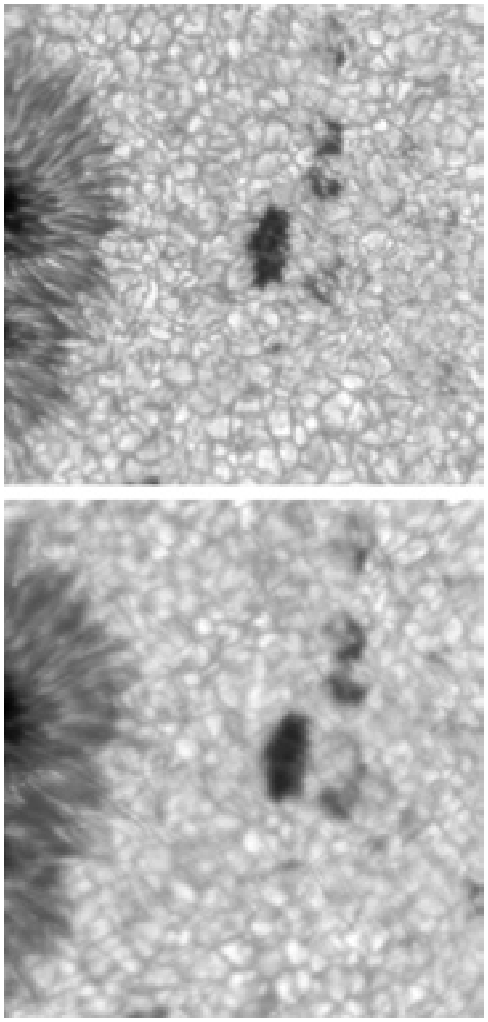


Figure 2. Image of an active region with (top) and without (bottom) AO correction. The field of view is 45 × 45 arcsec with a wavelength of 550 nanometers. The AO was locked onto the dark structure in the center of the field of view.

The tip-tilt mirror can now be driven either directly from the AO wavefront sensor or from a separate correlation/spot tracker system that operates at 3 kilohertz. Figure 2 shows an image of an active region taken with the AO loop closed and with the AO system off. Under seeing conditions that normally would preclude high-resolution images, the high-order system with its high, closed-loop bandwidth provided excellent imaging. The images were taken with a 10-nanometer-wide interference filter centered at 550 nanometers. A two-hour time sequence of AO corrected images was also recorded during the April run, and these data will be processed presently into a movie.

In the coming months, the project will focus on the completion of the optical setup at the DST, installation of the Big Bear AO bench, engineering runs at BBSO, optimization of reconstruction matrices and servo loop controls, and characterization of system performance at both sites. The DST system is to be commissioned in fall of 2003. The Diffraction-Limited Spectro-Polarimeter (DLSP), the main science instrument that can take advantage of the diffraction-limited image quality delivered by the high-order AO, is also scheduled for its first commissioning runs this fall. The DLSP is being developed in collaboration with the High Altitude Observatory in Boulder, CO.

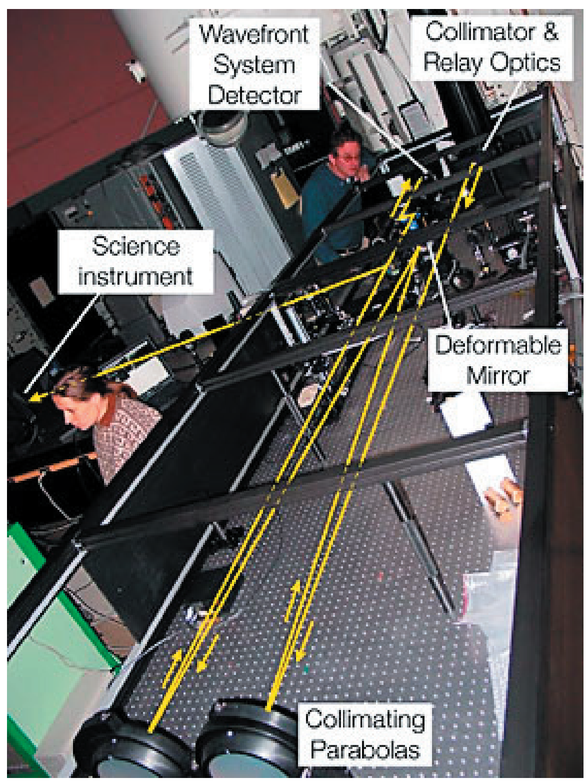


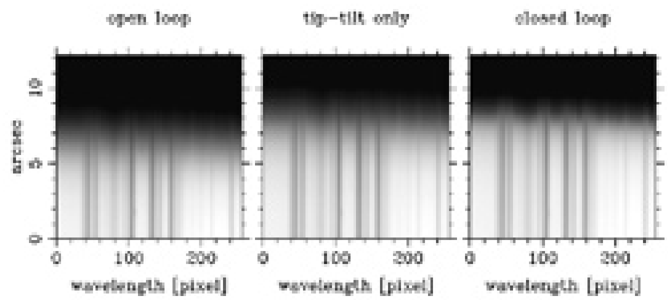
Figure 3. Dr. Maud Langlois and Dr. Thomas Rimmele prepare the AO system for a test run.

First Infrared Spectra with the McMath-Pierce Adaptive Optics System

Christoph Keller & Claude Plymate

The prototype adaptive optics (AO) system at the 1.5-meter McMath-Pierce Solar Telescope has been combined recently with the vertical grating spectrograph and the NIM infrared camera to record the first spectra in the thermal infrared at 4.8 microns. While the combined system has not yet been optimized, the figure already shows a substantial improvement in the spatial resolution across the limb, which is particularly evident in the off-limb CO emission. The presence of this off-limb emission is evidence for the existence of cool material in the otherwise hot solar chromosphere. The low-cost, 37-actuator AO system now makes it possible to study these molecular lines with high spatial resolution under most seeing conditions.

The prototype AO system is available for user observations on a limited, shared-risk basis. For more details on the AO system, see *www.noao.edu/noao/staff/keller/irao*.



Averages of 30 spectra (300-millisecond exposure) of the solar limb in the CO fundamental band at 4.8 microns, observed during poor seeing conditions. The spectrum on the left was recorded with the AO system off, the center spectrum was recorded with tip-tilt correction only, and the spectrum on the right was recorded with full AO correction. Note the off-limb emission of the CO lines. The diffraction limit at this wavelength is 0.8 arcsec. All three spectra are displayed at identical contrast settings.

ATST Design Progress

Jim Oschmann & the ATST Team

Over the last few months, the Advanced Technology Solar Telescope (ATST) team has continued to concentrate on key areas in preparation for the Conceptual Design Review. In particular, the enclosure trade study has been a high priority. Below, we highlight some examples of that work and summarize recent progress in telescope, optics, instrumentation, and systems engineering.

Enclosure Trades

Shortly after the workshop held last October, we developed a concept for the enclosure that combined desirable features from non-co-rotating and co-rotating designs, which we refer to as the "hybrid" design. Development of this hybrid concept was a direct result of feedback from the workshop. In the last *Newsletter,* we discussed the thermal considerations to be addressed. Led by Mark Warner, we have been working on two collapsible concepts to allow comparisons for this trade-off study. Two of the concepts being looked at are shown in figure 1. We are also working on a clamshell-based design that is compatible with the telescope concept.

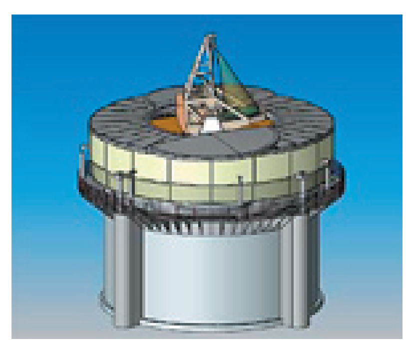


Figure 1. Two ATST enclosure concepts. The left shows a view of the hybrid co-rotating dome. The right is a collapsible dome based upon two facilities built for the US Air Force.

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ATST Design Progress continued

Thermal Considerations

In support of the enclosure trade study and the thermal issues concerning the optics areas, Nathan Dalrymple has continued to expand our understanding of thermal control needs. He and Thomas Rimmele have been conducting tests at Big Bear during the past several weeks to help quantify the enclosure-heating contribution to local seeing. Thomas has been measuring wavefront effects as the dome heats up, using an adaptive optics wavefront sensor and knife-edge test, and Nathan has been measuring the thermal differences. He has also completed dome temperature measurements at Gemini North with the help of Mark Warner and Chas Cavedoni (Gemini). Measurements from thermal sensors (see figure 2) are being used to help pin down the thermal modeling being done.

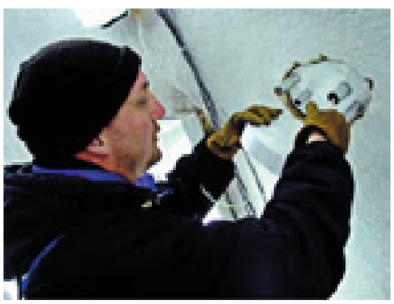

Figure 2. Dave Hauth (NOAO) installing sensors at Gemini North for ATST.

We also hope to measure small-scale effects using a phase-measuring interferometer. Some initial lab tests with a commercial interferometer have just been completed in Tucson by Eric Hansen (Gemini) and Gary Poczulp (NOAO).

Telescope and Facility Design

The telescope mechanical design has been filled out with such details as cable wrap concepts and other required necessities to provide adequate sizing of the overall facility, including pier and coudé labs. The three-dimensional solid models are being translated into finite element models for the telescope, pier, coudé lab, and interface to the ground. This will allow not only initial gravity and stress analysis, but also dynamic wind loading. The degree of stiffness achievable will relate not only to enclosure or protection needs, but also to fast tip-tilt active-mirror compensation needs. Figure 3 shows the latest telescope, coudé, and pier concept.

This design has many considerations beyond cable wraps and drive mechanisms. In the coudé lab area, the flooring has been sized to take into account the bending that might occur as one sets a multiton instrument on one part of the floor. The goal is to have any resulting motion at other instrument locations be a small part of any alignment tolerances. Initial gravity loading of the structure defines the active optics alignment needs.

Jeff Barr has completed visits to all six sites under consideration. He is completing reports on site-specific construction issues, and is leading an initial layout of support building options that can be adapted to any of these sites. Some of these details will be input to the system-level finite element model to better understand the range of wind shake and interface issues required for the six sites.

Optics

Ron Price has visited several of the manufacturers performing primary mirror fabrication and polishing studies. The key outcome is feedback on manufacturability of the 4-meter off-axis primary, including cost and schedule estimates. Ron Price and Nathan Dalrymple have been outlining first-order thermal control needs for the optics. Earl Pearson (NOAO) has been investigating primary mirror thermal modeling in detail to address concerns in a number of areas, such as support system interference with our desired thermal control.

The ATST baseline optical design has recently been updated with the help of

Figure 3. Telescope and pier.

Ming Liang (NOAO). We have kept the primary and secondary designs nearly unchanged. However, we have modified the relay optics to include a collimated interface to the coudé lab area. This allows greater flexibility in adapting to instrumentation needs at either coudé lab level. This new baseline telescope optical design, along with several concepts for interfacing to instrumentation, is available on the ATST Web pages. Included are several variations of multiconjugate adaptive optics concepts that could be adapted to this new baseline.

Instrumentation

Several partner groups are now producing optical concepts for ATST instrumentation. The new baseline and interfacing optics work just described resulted from interactions with our partners. The options on the Web for interfacing now include f/20 and f/60 focal planes. For each, there are dual-mirror and transmitting lens

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ATST Design Progress continued

methods suggested to flatten the focal surface presented to the instrument location. There are also single-mirror options for small fields or for cases where diffraction-limited performance is not required over the entire three arcminute field. From this work, it is clear that we will be able to provide good performance at any f ratio between the examples given on the Web. We will continue to work closely with each of the instrument design teams to investigate which options best meet their requirements.

Controls and Software
Bret Goodrich and Steve Wampler have been evaluating four methods of implementing a common infrastructure for the ATST control and software communications environment. These include LabVIEW using the SOAR communications additions, EPICS (the Alma Control System), and NDDS (Networking Delivery Data Service) from RTI. They have also begun more detailed discussions with our partners in the area of instrument software, controls, and data requirements.

Systems Engineering
Rob Hubbard has been developing our system-level error budgets. His priorities have been diffraction-limited performance in the visible spectrum with adaptive optics, best-case seeing limited in the near-IR using closed-loop active optics, and open-loop coronal use. In the near future, we will be publishing these initial error budgets, as well as analysis supporting the major trades, such as the enclosure.

Upcoming Milestones
The major, near-term milestones include the Conceptual Design Review scheduled in late August, site selection in October, and completion of the construction phase proposal near the end of this calendar year. The ATST Web site is kept up to date with the latest documentation, and we encourage the community to review the posted material and send comments or suggestions to our staff at any time.

SOLIS

Jack Harvey & the SOLIS Team

In the very near future, we will celebrate first light with the vector spectromagnetograph (VSM), the major SOLIS instrument. With luck, this will be the case for the full disk patrol (FDP) as well. And, with the move of the VSM from our basement lab, the integrated sunlight spectrometer (ISS) will be able to receive sunlight again from a rooftop heliostat. Thus, it is a pretty exciting time for the SOLIS team.

After the spectrograph section of the VSM was aligned, the 50-centimeter aperture telescope section was installed and aligned very rapidly. The front entrance window was installed and the entire instrument was pressurized with helium. The helium leak rate was significantly less than expected, and the liquid cooling system works flawlessly. A transfer rate problem of accumulated digital data from the VSM to a storage area network was addressed with considerable, but not yet complete, success. An end-to-end data flow test is the next milestone for the VSM system. The guider for the VSM is the only hardware component not completely finished. The first observations will be made open loop, and the guider installed shortly after the instrument is placed on the SOLIS mounting.

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The SOLIS VSM instrument being prepositioned for installation on the mount.

SOLIS continued

Almost all of the optics for the FDP were installed and aligned using a laser. The instrument has three separate optical paths (1083 nanometers, visible, and guider beams) and their mutual alignment was an interesting exercise. Work is now in progress to complete the alignment of the two focal plane cameras.

Two modules are nearing completion that will finish the hardware aspects of the ISS. These are the so-called extinction monitor (see last issue of the *Newsletter*) and the 8-millimeter aperture light feed to the fiber optic that scrambles sunlight and directs it into the ISS.

Construction is also underway at the Kitt Peak Vacuum Telescope for the installation of SOLIS there.

The SOLIS VSM instrument installed on the mount at the GONG farm temporary site, with the installation team, from left to right: Kenny Smith (Mid-States Co.), Benny Bracamonte (Marco Co.), James Robinson, Sean Hofhine (Mid-States Co.), George Luis, Dave Jaksha, Dave Hauth, Neill Mills, and Lou Lederer.

NSO Aladdin Camera Project

Matt Penn & the NAC Project Team

The NSO Aladdin Camera (NAC) project is aiming to achieve first light in the first quarter of 2004. The NAC will virtually quadruple the current NSO infrared (IR) data collection capability, and is likely to have the lowest readout noise of any NSO IR camera. The NAC electronics and control computer should be completed by mid-2003, and the NAC dewar is in the final design stages. The dewar, contracted to Mauna Kea Infrared, will be a closed-cycle cooled system with a large optical bench for a future cold optics upgrade (likely a two-to-one demagnification system). The initial cold optics will simply include a filter wheel and a fold mirror, allowing the spectrograph or telescope to be focused directly on the detector (see figure). Integration and testing of the system is expected in early 2004.

The NAC will replace the decade-old 256 × 256 IR array, and will make observations in the 1–5 micron region. Initial scientific projects will include spectropolarimetry at 1.56 microns to measure active-region solar magnetic fields; spectroscopy of Helium and CO at 1.08, 2.3, and 4.6 microns to study the solar chromosphere; and exploration of the solar spectrum at 4.1 microns to map coronal emission from the newly discovered eight-times ionized silicon ion. The NAC will be designed as a flexible system to be used with the spectrograph or IR Fabry-Perot filter, or in direct broadband imaging experiments at the NSO solar telescopes. The NAC should be available to the science community by mid-2004.

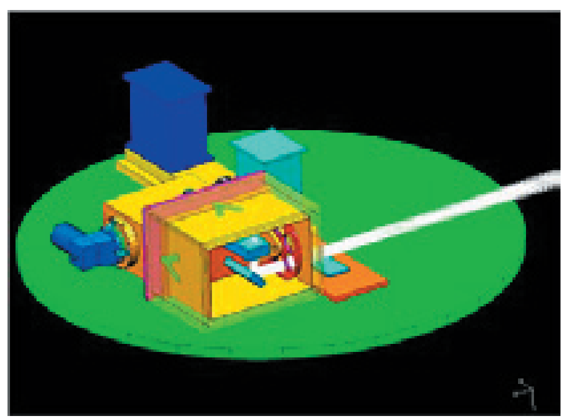

Figure 1. The initial layout for the NSO Aladdin camera dewar on the main spectrograph at the McMath-Pierce telescope with the initial simple optics layout. Dewar space is available for future upgrades to the cold optics.

The NAC project team includes Matt Penn, Jeremy Wagner, Dave Jaksha, Mark Giampapa, and Claude Plymate.