Reminiscences of Sacramento Peak

Several scientist were invited to present their reminiscences about their time at Sac Peak and if desired how it influenced their career. We held reminiscence sessions each day in a final session. At the beginning of the sessions, Steve Keil presented a brief (well perhaps not so brief) history of Sacramento Peak Observatory (SPO) at the beginning of the first session to provide a backdrop for the reminiscences. The article in this compilation by George Simon presents his thoughts on, and a more detailed summary of the early (Air Force) history from the observatories founding in 1947 to 1976 when the observatory transferred from Air Force to National Science Foundation. A special thanks is due to Kevin Reardon for placing many old Sac Peak photos on line at https://www.flickr.com/photos/142791220@N07/albums as well as historical documents at https://drive.google.com/drive/folders/0B6ZaddlVEzqMVHRfbkNkSjBxQk0.

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Sacramento Peak Brief History

Stephen Keil

What follows is a short summary of the entire Sacramento Peak Observatory (SPO) history from its founding to the present as presented at the meeting (with some embellishments). While I mainly discuss instruments, results and scientist roles, we must recognize that it is the technical and observing staffs played a key role in making it all happen. The information from 1947-1976 comes primarily from references 1,2 &3. From 1977 on, information comes from National Solar Observatory (NSO) and National Optical Astronomy Observatory (NOAO) planning documents (references 4,5), from Annual Reports in the Bulletin of the American Astronomical Society (BAAS), and from personal recollection, which is probably faulty.

Prof. Donald Menzel played the key role in the establishment of the observatory. He had also been responsible for establishing the Climax Observatory in Colorado. During WWII, coronal data from climax was used to help forecast solar disturbances to military communications. From his experiences in communications during WWII with the value of knowing what the Sun was up to, and the fact that weather often hampered data collection from Climax, Menzel thought it prudent to develop a second observatory with better or at least different weather patterns. Having two observatories would give much better coverage of solar disturbances. During his search for funding, he met Marcus O'Day of the Air Force. Marcus was an upper atmospheric scientist interested in developing rocket program at White Sands NM, with a strong interested in solar effects on the earth's upper atmosphere. To shorten the story, O'Day obtained the funding to build an observatory, but wanted it located at a site to coordinate with his upper atmospheric experiments. Menzel enlisted Walter Roberts of the newly form High Altitude Observatory in Boulder, which operated Climax, to help with site selection. The president of American Airlines lent them a plan (and himself) to fly over sites in the southwest, and they noted Sacramento Peak, which appeared to be a good site and more importantly, met O'Days criteria of being near White Sands (see the article by Simon below for more detail).

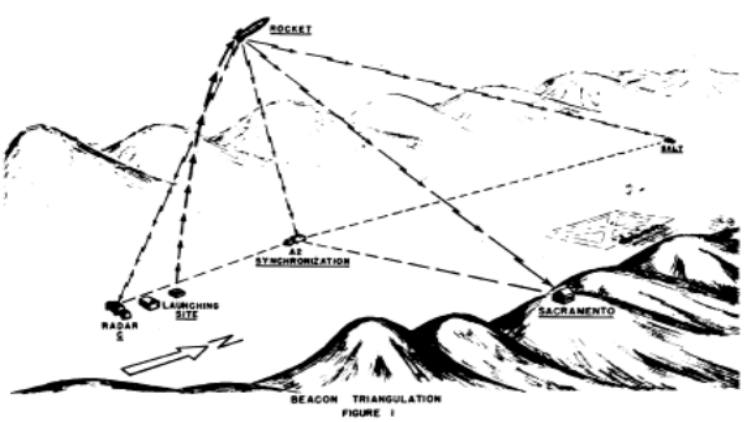


Fig 1. Sacramento Peak lower right gives a line of sight view of rockets launched from White Sands Missile Range.

Fig 2. Don Menzel, Robert Condon and Walt Roberts discussing Sac Peak

Fig 3. Above, from left to right: Dr. Charles R. Burrows (Cornell University), Dr. Marcus O'Day (Geophysics Research Directorate, Air Force Cambridge Research Center), Dr. Donald Menzel (Harvard College Observatory), and Maj. James Sadler (first Commander of Sac Peak) confer on plans the Peak, April 1952. Courtesy of the U.S. Air Force. Shortly after taking this photo, Jack Evans became superintendent of Sac Peak. Cornell had a radio program at the Peak, but it was soon cancelled due to radio interference.

Fig 4. Left: Jack Evans and Harlow Shapley. Jack was a student of Shapley's at Harvard, and later hooked up with Menzel and Walt Roberts. Jack took a position working at Climax. Later Jack would play the key role in making Sac Peak a world-class observatory for solar physics.

Figure 5 summarizes the history of Sac Peak evolution in names and management organizations. It did not become the Sacrament Peak Observatory until 1956. When Menzel was unable to get Harvard to grant tenure to the senior staff at Sac Peak, the Sac Peak staff became a combination of Air Force and contract employees. NAO stands for the National Astronomy Observatory, which later became the Kitt Peak National Observatory (KPNO). The AF operated SPO until 1976 and then SPO transferred to the National Science Foundation (NSF). NSF awarded AURA Inc. (Associated Universities for Research in Astronomy) the contract for SPO operations. In 1982, the solar program at KPNO and SPO were combined into the National Solar Observatory. In 1983, NSO, KPNO and CTIO (Cerro Telolo International Observatory in

Chili) where combined to form NOAO (National Optical Astronomy Observatories). NSO became independent of NOAO in 2000. SPO operated under NSO until 2017, when NSO began the process of divesting Sac Peak and its assets on Kitt Peak in order to generate funds for operating a new large aperture telescope on Maui.

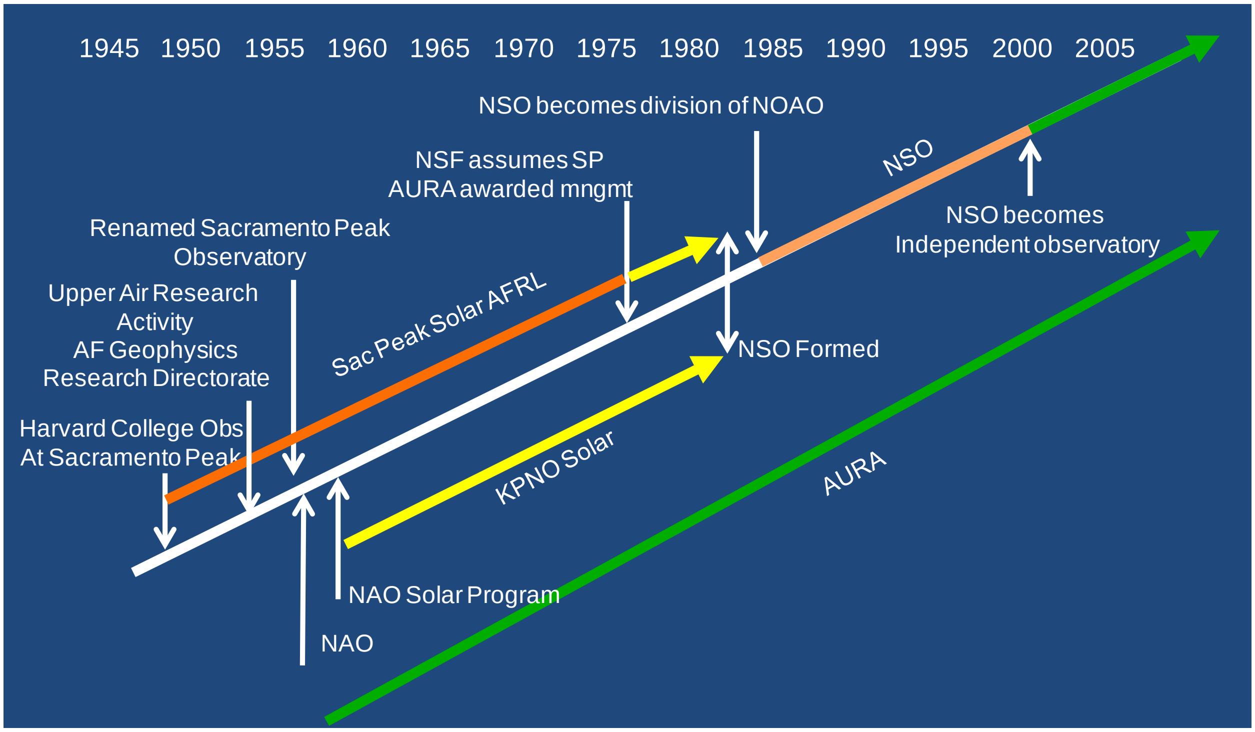
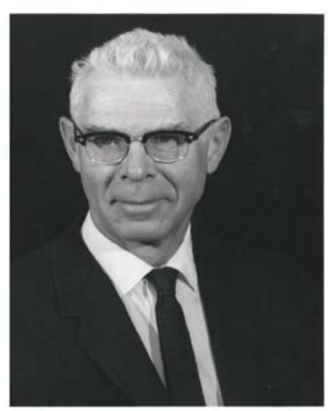


Fig 5. The figure presents time lines for the management and funding of SPO and NSO.

The remainder of this article presents a time line of SPO evolution, primarily as marked by the evolution of its facilities and instruments. However, one cannot proceed without a few words about NSO directors, who along with the staff helped shape the observatory.

Directors



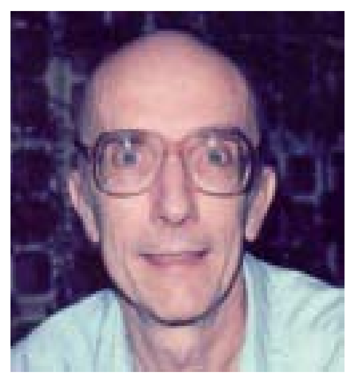
Maj. James Sadler was the first Sac Peak installation commander and served from 1948 – 1951. No picture is available (see Figure 3).

John W. (Jack) Evans, appointed superintendent of the observatory in 1952, was the longest serving director. When the observatory was renamed the Sacrament Peak Observatory in 1956 Jack's title was changed to director. Jack served through 1975, and took the opportunity in the transition from AF to NSF to step down. Before becoming director and while still working a Climax and Boulder, Jack worked on the design of new large aperture coronagraphs along with Walt Roberts, one for Sac Peak and one for Climax.

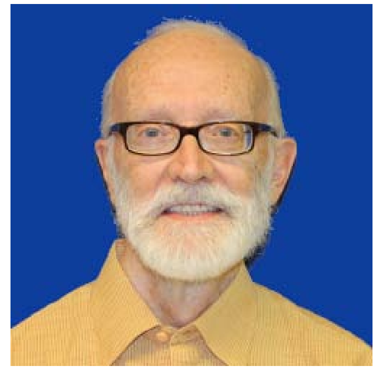
Richard (Dick) Dunn served as interim director under AURA/NSF from 1976-1977 and guided the transition from the AF. Dick was the driving force behind much of the instrumentation at Sac Peak. His need for higher resolution observations was the motivation behind his design and development of the Vacuum tower telescope (now the Richard B. Dunn Solar Telescope or DST) at SPO. He pushed the adaptive optics program at SPO in late 70s and 80s.

Jack Zirker was director from 1977 to 1982, and interim direction of the newly formed National Solar Observatory (NSO) until the first NSO director, Robert Howard was hired in 1984. He reported to AURA and AURA gave him the herculean task of developing stronger bonds between SPO and KPNO-Solar. Jack's background was in coronal physics. Jack first came to SPO in 1956 and played a strong role in the coronal program. He left SPO in 1963 to take a position at the University of Hawaii, joining Frank Orall, who had also spent time in the 50s at Sac Peak, and John Jefferies. In order to strengthen the solar program in Tucson, Jack shifted several positions from Sac Peak to Tucson.

Robert (Bob) Howard became the first NSO director in the newly formed National Optical Astronomy Observatories (NOAO) and served from 1983 – 1986. Howard came to NSO from the Mt. Wilson and Las Campanas Observatories of the Carnegie Institute of Washington in Pasadena. His work included instruments for measuring and studies of solar magnetic fields, rotation, solar oscillations among many other things. Bob reported to the new NOAO director, John Jefferies. SPO now found itself in a position three times removed from its funding agency: NSF/AURA/NOAO/NSO/SPO and KPNO-Solar. NOAO had budget issues in 1984 and 1985, and Jefferies decided one way to meet the shortfall was to close SPO or run it as a remote site. Whether this was the old Washington Monument ploy, or he truly thought SPO was the least valuable I am unaware. Bob found himself in the unenviable position of having to close over 50% of the newly formed NSO program. Fortunately, community reaction kept SPO open along with increased funding from the Air Force.



John Leibacher assumed the reins of NSO from 1986-1992. John came to NSO in 1984 from the Lockheed Research Laboratories in Palo Alto with his primary interested in solar oscillations. Under John's directorship, NSO developed a proposal for a network of solar oscillation telescopes and organized a large segment of the solar community into the Global Oscillation Network Group (GONG). John served as editor for the journal Solar Physics. John appointed Raymond Smart as his deputy director for SPO. Ray's primary interest was in coronal observations and interpretation. Working with Serge Koutchmy, Ray and Serge developed a series of reflecting coronagraphs (Mirror Advanced Coronagraphs or MAC) using super polished mirrors. Both 5 cm and 15 cm aperture coronagraphs were completed and work began on a 50 cm coronagraph.



Jacques Beckers was director from 1993-1998. Beckers worked at Sac Peak from 1963 through 1979. He left in 1979 to take a position with ESO and then with NOAO as head for the Advanced Instrument Program. While at SPO, Jacque developed the Universal Birefringent Filter (UBF) and was active in improving observations at the Dunn Solar Telescope (VTT at the time). Jacques was interested in pursuing a large aperture reflecting solar telescope and began the CLEAR (Coronal and Low Emissivity Astronomical Reflector) project. Jacques took a year off in 1996 to pursue the CLEAR design and Doug Rabin became the acting director during his absence. Unfortunately CLEAR never received strong community endorsement and was not funded.

Stephen Keil was director from 1999-2013. Stephen had worked at the observatory from 1979 to 1998 as a member of the Air Force staff, with interests in solar activity, high-resolution observations of solar magnetic fields and magnetoconvection and the effects of solar activity on the Earth and AF systems. One of the first priorities during Keil's directorship was taking NSO out of NOAO, thus clearing the way propose for a large aperture solar telescope without going through internal NOAO competition and politics. Both the director of NOAO and the president of AURA supported the separation. NSF signed off on it in 2000 and AURA/NSO obtained a separate cooperative agreement with NSF. The

NSO quickly submitted a design proposal to NSF for designing a large aperture solar telescope and conducting a site survey. The proposal was funded and NSO embarked on a two-decade effort to produce a 4-meter aperture solar telescope.

AURA appointed Valentin Martinez Pillet NSO director in 2013 and he is still serving. Valentin came to NSO from the Astrofısica de Canarias in La Laguna, Tenerife, Spain. Valentin background is in high resolution stokes polarimetric observations of solar magnetic fields. He is responsible for the reorganization of NSO with a new headquarters in Boulder and an operating facility on Maui, as well as the completion of DKIST.

Visitors, Graduates and Undergraduates

SPO has always been a magnetic for members of the solar community. Jack Evans set the tone early on with his open policy allowing visitors to use the telescope. As an Air Forces observatory, it did not necessary have to be open to visitors. The visitor program insured that Sac Peak was a vibrant place to work. While it would be impossible to list all the visiting scientists a brief sample gives you the flavor:

Franz Deubner (Germany), Serge Koutchmy (France), Tokio Tsubaki (Japan), Oddbejorn Engvold (Norway), Jack Thomas (U.S.), Klaus Jockers (Germany), Richard Müller (France), Gianna Cauzzi (Italy), Roberto Falciani (Italy), Rob Rutten (Netherlands), Dimitri Mihalis (U.S), Peter Wilson (Australia), Kees Zwann (Netherlands), Ejidio Landi (Italy), Hank Spruit (Germany), Piere and Nichol Mein (France), Peter Mehltretter (Germany), Oskar von der Luhe (Germany), Eugene Parker (U.S.), Alan Title (U.S.), etc

Some came for observing runs, others to stay for one or two years and interact with the SPO staff. SPO also supported many graduate student theses over the years and in 1969 began a formal student program that brought 6-10 graduate students to the observatory for the summer. Staff scientist mentors assigned to each student gave them projects in solar research, which often led to thesis topics. In 1985, an additional formal program for undergraduates began, many of whom were enticed into careers in solar research. The student programs continue to remain strong.

Development of Sacrament Peak Observatory as an Air Force Facility

The following tables and images give a brief glimpse at the development of Sacramento Peak up until its transfer to the NSF. The certainly do not cover all aspects of the development, in particular there is little mention of science enabled by the changing instrumentation. The article by Simon below provides information of these years in more detail.

Date	Event	Notes
<1947	• Coronal Data from Climax Observatory used in WWII for predicting solar activity • Donald Menzel would like to see a second observatory to complement Climax and increase coverage • Menzel and Marcus O'Day of the Air Force team up to sell the idea	Menzel had founded Climax and his former student, Walter Roberts operated it. Roberts went on to found HAO and NCAR O'day was interested in a site near White Sands Missile Range to support his upper atmosphere program.
1947	• Air Force awards Harvard a contract for a site survey to select a location for a solar observatory. Subcontract to the newly formed High Altitude Observatory in Boulder CO. Don Menzel of Harvard and Walt Roberts of HAO spearhead the Survey. • Menzel and Roberts fly over many southwest mountains looking for a site and note Sacramento Peak. • September: Two resident observers begin data collection of observing conditions at Sacrament Peak (Sac Peak) • December: Menzel and Roberts tentatively recommend Sac Peak	The president of American Airlines flew them in his private plane
1948	• March: White Mountains near Bishop California considered as alternate site • April: DOD Research and Development board approves Sac Peak as final site • Harvard/HAO awarded contract to develop the observatory	During a site visit Roberts was caught in a blizzard and nearly froze
1949	• Harvard/HAO team starts observations with 11 cm (4.5 ") coronagraph on 2.4 m (8') spar in a sliding roof observatory. Its primary function is a coronal activity monitor • A Sears and Roebuck grain bin was purchased and made into a rotating dome, named the Grain Bin Dome, a 3 m (10') spar was added • A 15 cm (6") prominence telescope is mounted on the 3 m spar • Construction of a 40 cm (16") coronagraph and 8 m (26') spar begins in Boulder by Jack Evans and Walt Roberts (Lyot consulting on optics) • Daily radio observations of the Sun begin (Cornell)	WW II showed that coronal activity could interrupt military communications Lyot had invented the coronagraph. Jack had been working with Roberts at Climax
1950	• Sac Peak became known as the Sacramento Peak Station of the High Altitude Observatory jointly operated by Harvard University and the University of Colorado under contract from the Air Force	
1951	• March: 6 cm (2.5") Hydrogen Alpha Flare Patrol camera mounted on the 3 m spar in the Grain Bin and daily observations are started • April: Sac Peak is established as the Upper Air Research Activity under the Air Forces Geophysics Research Division (later to become the Air Force Cambridge Research Laboratory) • Sac Peak operated by a combination of military and civilian AF employees	Menzel's plan of having Sac Peak senior staff become tenured Harvard members was not approved by Harvard

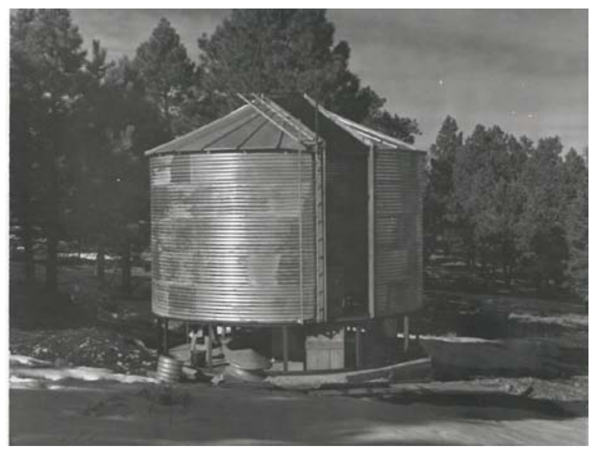


Fig 6. Upper left and right: The early road to Sac Peak was rough, especially in Winter. Middle left: Rudy Cook and George Schnable with the 11 cm spectrograph, fist science instrument at Sac Peak and only the second U.S. coronagraph, the first was at Climax. Middle right: the Grain Bin Dome during construction. Lower right: The 3m spar in the Grain Bin with an Acme camera shown for prominence movies.

1952	• Jack Evans appointed superintendent of Sac Peak • Renamed the Upper Air Research Observatory • Evans hires Richard (Dick) Dunn • Construction of a new facility to house the 8 m spar and 40 cm coronagraph begins • 15 cm white light telescope installed on the 3 m grain bin spar • Staff: Dunn, Evans (sup), J. Warwick, C. Warwick • 10 Redwood houses built along the ridge to house staff, Main Lab office building completed and apartments to house visiting scientist	Jack was another Harvard graduate Dunn would prove to be one of the greatest solar instrument and telescope designers ever The houses are still in use today.
1953	• New Facility (Big Dome) completed at Sac Peak and 8 m (26') spar installed (Spar so well balanced only 2.5 mouse power required to drive right ascension, 1 mouse power = 1/10,000 horse power) • 40 cm coronagraph installed on 8 m spar, used for both coronal and on disk measurements, used for the next 60+ years with some modifications.	Evans and Roberts designed spars and coronagraphs for both Climax and Sac Peak with some collaboration from Lyot on the coronagraph.
1954	• Cornell radio observations cease due to interference from Holloman AF Base	
1955	• 13 m (43') Littrow spectrograph installed in the Big Dome fed by the 40 cm coronagraph • Helicopter landing strip built • 38 cm (15") chromospheric and prominence camera installed on the 8 m spar	The Littrow was a horizontal double pass spectrograph with low scattered light fed by the 40 cm coronagraph
1956	• Upper Air Research Observatory name changed to Sacramento Peak Observatory (SPO) and Jack Evans becomes its first director • 1956 Staff: Dennison, Dunn, Evans (dir), Orrall, H. Smith,E. Smith, Zirker • Dick Thomas, Grant Athay, John Jefferies were frequent visitors providing theoretical support	Funding for SPO is now going through the Air Force Cambridge Research Laboratory (AFCRL)
1957	• Patrol coronagraph installed on Grain Bin Spar • Universal Spectrograph installed in Big Dome • Evans designs a telescope for Project Stratoscope, a balloon borne telescope flown my Martin Schwarzchild to measure solar granulation	Showed the true size and non-static nature of small scale convection
1958	• Six Redwood Houses built on Sac Peak (previous housing was Quonset buildings) • A concept for an evacuated solar tower telescope (VTT) is put forward to the Air Force	The proposal is for a 1.5m solar telescope
1959	• Spectroheliograph installed at the Big Dome • Development work on VTT begins	Daily full disk scans in Hα (off and on band), He 10830, and Ca K-line
1960	• Coelostat and secondary mirror installed at the Big Dome feeding a 30 cm horizontal telescope providing a solar image to all instruments • The road to Sac Peak is finally paved	Getting stuck in the mud on the way up to mountain was a common occurrence

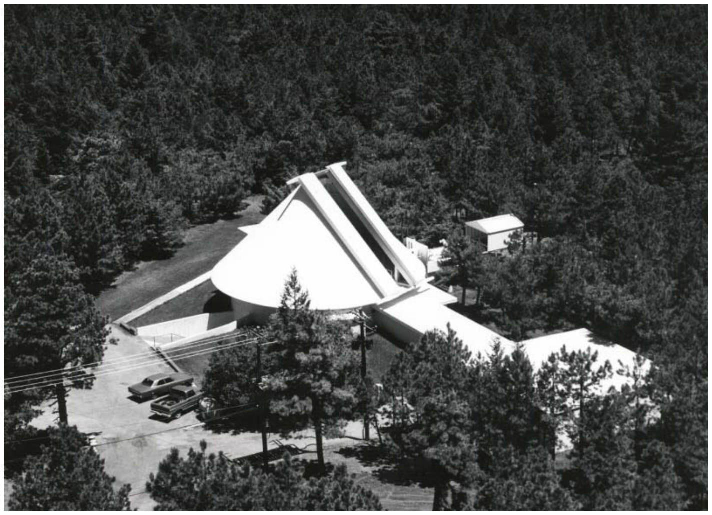
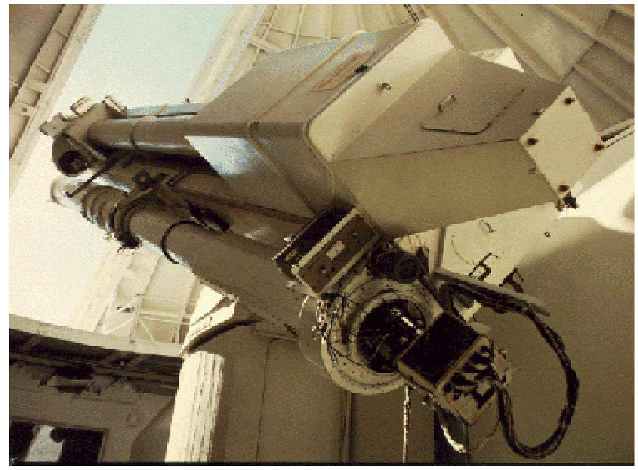
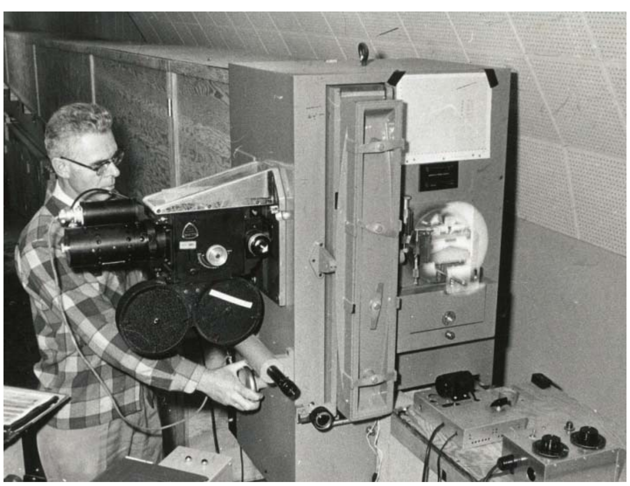
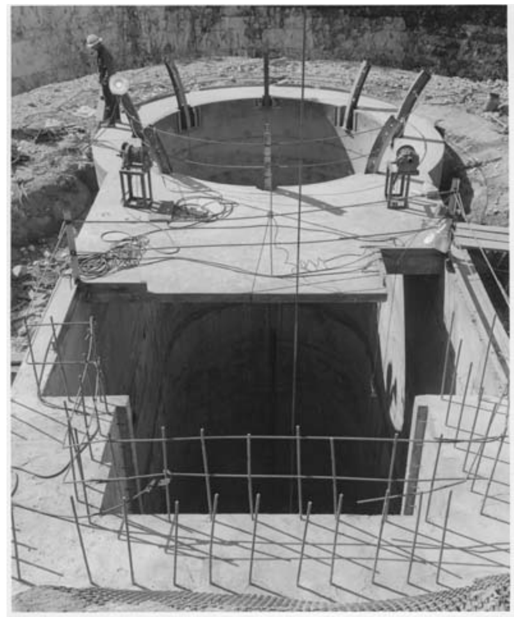



Fig 7. Upper left is a photo of the Big Dome (renamed later as the John W. Evans Solar Facility or ESF). The picture was taken after the Coelostat was added in the slid- off shed see to the right of the main dome, and after offices and film developing facilities were added shown to the lower right of the dome. Upper Right, the 8 m spar is shown pointing out of the dome. The main 40 cm coronagraph shown on top the spar. Middle left: Lou Gilliam and Arnold Green are rebalancing the 8 m spar after adding an instrument. Middle right: Installing instruments and a camera on the spar could be a major effort. Bottom: Jack Evans is tweaking the ESF Littrow spectrograph for an observation.



1961	• SPO staff: Dunn, Dennison, Evans (director), Orall, H and E Smith, White, Zirker	
1962	• 40 cm (16") magnetograph telescope installed on the 8 m spar in the Big Dome along with a Doppler Zeeman Analyzer (DZA) • By 1962 there are 70 personnel working at SPO, 10 military, 28 civil service (7 PhDs) and 32 contractors. In addition there are 12 visiting scientists • Solar 5 m oscillation were discovered by Leighton, Noyes, and Simon at Cal Tech and their pursuit would be a major driver at both SPO and KPNO-Solar	Jack Evans had data that showed the oscillations but he had attributed them to turbulent noise from convection
1963	• Hilltop Dome constructed and a 3.6 m (12') spar installed • Grain Bin instruments (flare patrol and white light telescope) transferred to Hilltop • Beckers and Simon join the SPO staff, H. and E. Smith leaves	Hilltop Dome becomes the main solar activity monitoring site
1964	• Dick Dunn begins final design work begins on VTT • Additional space for offices and film processing added to Big Dome	
1965	• Dunn designs a photoelectric flare spectrograph to measure flare emissions in 40 spectral lines	
1966	• Spring: Construction starts on the VTT • 10 additional houses completed at Sac Peak, mainlab addition finished • Photoelectric flare spectrograph install in Hilltop Lab and fed by innovative Gregorian heliostat, used by NASA for Skylab support	SPO is developing a substantial live in staff.
1967	• Dunn designs two photographic flare spectrographs, one for Hilltop and one for the 40 cm Coronagraph to make rapid measurements of flares • Mainlab computing center developed (XDS Sigma 5) for data reduction	
1969	• VTT Completed with evacuated light path to remove internal telescope seeing, mercury bearings used to support telescope and separate mercury bearing to support the entrance coelestat. • All SPO contractor personnel converted to civil service	
1971	• Photographic Eschelle Spectrograph installed in VTT	
1973	• Diode Array installed on the eschelle spectrograph • Jacques Beckers designs a Universal Birefringent Filter which is installed at VTT, the UBF was tunable from 420 to 700 nm angstroms with a variable bandpass of 4 to 13 pm.	Almost any six wavelengths could be recorded simultaneously as the solar disk was scanned, so that velocity, magnetic or intensity images could be rapidly generated
1974	• Air Force notifies SPO of its intention to discontinue funding as a result of the Mansfield amendment in Congress • AF contracts SPO to build the Solar Optical Observing Network (SOON) telescopes for the Air Weather Service • Daily coronal patrol ceases operation • 38 cm (15") prominence telescope removed from Big Dome 8 m spar • HAO closes Climax Observatory and begins construction of Stokes polarimeter and coronal emission-line photometer for installation at the Big Dome.	
1975	• First SOON telescope completed and installed in Hawaii	



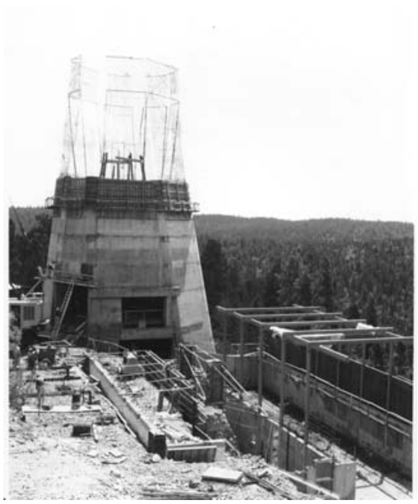


Fig 8. Upper left is a photo of Dick Dunn as he designs the VTT, not that his none beer hand indicates its height. Upper right and middle images are photo during construction, not sure OSHA would have approved the way those gentlemen are standing. Left: The finished DST extends 130 feet above ground and another 230 below. This allowed a very long focal length mirror. The light path from the entrance window seen on top to the primary and back to the ground level observing stations is evacuated to reduce internal telescope seeing.

SPO Transfer to NSF and Operations under AURA

1975-1978

After the Air Force announced their intention of divesting Sac Peak, there was considerable activity to determine its fate. In 1975, Jack Evans steps down as director after a 23-year tenure. Leo Goldberg informed the AURA Executive committee of the planned AF action suggesting they should be interested. NSF formed a blue-ribbon panel to determine the fate of SPO chaired by Martin Schwarzchild. His committee recognized SPO as the premier solar facility both in the US and internationally and recommended that NSF assume responsibility for its operation as a national facility. In July of 1976, NSF accepts interim responsibility for SPO and AURA agrees to serve as interim contractor for SPO operations. AURA appoints Jack Zirker as director of SPO and the era of AURA management begins. AURA asks Jack to develop better coordination between SPO and KPNO solar programs (AURA also operated KPNO). Leo Goldberg in the meantime is urging NSF to assess the overall national effort in solar physics, which helped set the stage for the eventual formation of a National Solar Observatory.

SPO and KPNO-solar staff hold a joint meeting later in 1976 to discuss future-directions of the observatories and solar oscillations, stokes polarimetry and the solar-stellar connections emerge as rewarding areas. Following the meeting, sun-as-a-star observations in the Ca II K-line begin at SPO and several other programs, some joint with the High Altitude observatory begin. In 1977, the first stokes polarimeter (STOKES I) is installed in the Big Dome. This is a joint HAO/SPO project led by HAO. It uses the 40 cm coronagraph to measure on disk vector fields using a single point detector. HAO also develops a K-Coronagraph Emission Line Photometer (KELP) for installation in the Big Dome. KELP measured coronal magnetic fields in the plane of the sky. Ray Smartt joined the SPO staff in 1977 and began development of the One-Shot coronagraph. The One-Shot is so named because it simultaneously views the entire corona out to two solar radii.

Meanwhile, back in D.C., NSF is still wondering what to do with SPO, so in 1977 they appoint a special advisory committee with Art Walker as chair. The committee recommends that NSF continue to support SPO as a national observatory with both visitor support and a strong research staff. NSF takes the advice and solicits proposal for the operation of SPO. At their annual meeting in early 1978, AURA discusses their proposal for SPO operation. In April of 1978, NSF awards AURA the cooperative agreement for SPO operations. AURA now has separate NSF cooperative agreements for KPNO, CTIO and SPO. Jack Zirker is appointed SPO director with a 5-year contract. During the transition from AF to AURA, several staff scientists leave for other positions and several new scientists are hired. Part of the SPO staff stays with the AF, after the AF decides to maintain a small research group at SPO that would continue to report to the Air Force Geophysics Laboratory. George Simon becomes Branch Chief of the Solar Research Branch of AFGL.

In spite of the uncertainty and politics of establishing SPO under NSF, science continues. Tim Brown and Jacques Beckers develop a concept for a Fourier Tachometer for measuring small (a few m/s) velocities in the solar atmosphere and construction of prototype begins as a joint SPO/HAO project. SPO assumes operation of the 48” AF photoelectric telescope in Cloudcroft, NM and builds a new photometer under, contract to the AF, to use there, thus furthering the Solar-Stellar connection program. NSO staff also realized that although the Vacuum Tower Telescope (VTT) has mostly eliminated internal telescope seeing through is evacuated light bath, atmospheric seeing still limits the quality of observations. Thus begins a long series of experiments and efforts to remove seeing. One of the first is a rubber mirror image improvement experiments at VTT by a U.C. Berkeley group, but it only works for stellar images. The article below by Rimmele recounts a history as well as his experiences in developing adaptive optics.

1979 – 1982

Fig 9. Stebbins's oscillation telescope preparing for a trip to the South Pole

In 1979, NSO completed the One-Shot coronagraph, mounted it on the Hilltop spar and, a series of full corona observations began. A team from Itek Optical Systems tested their Real Time Atmospheric Compensation (RTAC) system at the VTT. They demonstrate the feasibility of correcting for seeing, but only under rare conditions. They show that a fast mirror can remove first order image motion. SPO installs a White Light Flare Polarimeter on the Hilltop spar that observes white light flares in four continuum band passes to study energetics. The STOKES I polarimeter in the BIG Dome is upgraded from a point to a 2-D detector by HAO.

In Nov of 1980, Robin (Tuck) Stebbins takes the first of three oscillation experiments developed at SPO to the South Pole. The goal is to take advantage of the 24 hours of sunlight during the Antarctic summer to obtain a long baseline on solar oscillation, thus improving the resolution in the frequency domain. Dick Dun and his team finish developing and installing the SOON telescope system for the AF. This greatly improves the AF's ability to monitor solar activity and active region development. In 1981, NSO installs a 12 cm refractor white light flare patrol on the Hilltop spar.

Fig 10. Mauter, chief observer at the VTT

I should mention it was this constant development and renewing of instrumentation that kept SPO as one of if not the leading solar observatory. The VTT is the most subscribed solar telescope in the world. The strong observing staff led by Horst Mauter is a big factor in its popularity.

In 1980, John Jefferies, a member of the AURA Board, suggested taking solar out of KPNO and adding it to SPO. In Jan 1981, AURA begins an 18-month study of combining SPO and KPNO-solar. At the April 1982 AURA annual meeting the Board votes to combine SPO and KPNO-solar into the National Solar Observatory (NSO) and appoints Jack Zirker interim director. I assume NSF approved, although I found no documentation. At a later meeting in Nov of 1982 the Board resolves to combine NSO, CTIO and KPNO under one director with Associate Directors for each of the three observatories.

Fig 11. Part of Horst's collection of VTT visiting observers and technical staff in the 1970s.

1982 – 1989

Jack Evans and Tim Brown begin building a Mark II Fourier Tachometer in 1982. Tuck Stebbins implements improvements to the South Pole oscillations experiment and ships it in Oct to the Pole. At the VTT, where SPO relied on film and the linear diode array, to collect data, Multiple Diode Array (MDA) cameras are brought into operation, based on the 320x512 pixel RCA CCD. A fast tip-tilt mirror is installed in the VTT to remove image motion, but can only track on features such as sunspots.

In June of 1983, NSF approves the AURA plan for combining the observatories and, in Feb 1984 NSF, approves AURA's name and the National Optical Astronomy Observatory is born. NSO becomes a division of NOAO and SPO is a division of NSO. This effectively isolates SPO from direct contact with the NSF. AURA appoints John Jefferies as the first NOAO director. NOAO hires Robert Howard as the first NOAO Associate Director for NSO in August of 1984. Also in 1983, George Simon steps down as Branch Chief of the AF group and Steve Keil becomes the chief.

The new NOAO director faces a budget crunch in 1985 and decides to close Sac Peak. The closure plans leaked to the solar community before the SPO staff is informed. Community uproar then causes Jefferies to change plans; instead of closure he would make SPO into an observing station (without the strong research staff). NSF commissions a blue ribbon panel to recommend a course of actions. The committee, chaired by Eugene (Gene) Parker, strongly supports SPOs current operations. Their recommendation along with some additional funding from the Air Force keeps SPO open with a strong research component. Unfortunately, the increased AF funding comes from an earmark Congressman Joe Skeen, from the southern New Mexico district, placed on the AF 6.1 Funding line. Most of the earmark comes out of the budget of the AF group at SPO. Unfortunately, this affects the ability of the SPO AF group to continue its support of outside contracts with University and other groups that have been strong user of SPO. By the end of 1987, both John Jefferies and Bob Howard step down from their directorships. Sydney Wolff becomes NOAO director in 1987 and appoints John Leibacher from the NSO/Tucson staff as director. John was PI for the GONG proposal to NSF.

In spite of the politics, much of the 1980s witnesses the strong continuation of instrument development at SPO for the various facilities at Sac Peak as well as some SPO instrument development for the McMath on Kitt Peak. Emphasis is on studies of solar oscillations, large-scale motions in the solar atmosphere and, on improving high-resolution image quality. In 1984, Dunn develops both spectrally stabilized solar and stellar spectrographs. Along with Oskar von der Luhe, he begins experiments on correlation tracking. SPO implements a full disk capability at the VTT for Frank Hill to study global solar oscillations. Stebbins returns to Antarctic with his solar oscillations experiment. In 1987 NSO moved the Fourier Tachometer from Sac Peak's Big Dome to downtown Tucson where it was fed by the roof heliostat on the NOAO/NSO building. NSO believed this would provide longer observing runs because of the better weather and provide stronger observing support for Antarctic experiments. During the same period, NSF decided to fund the GONG proposal. Dick Dunn designs the turrets for the GONG telescopes and builds them at Sac Peak. 1987 also witnesses the beginning of an in-house Adaptive Optics program under Dunn and the development of an operational correlation tracker system by Thomas Rimmele (a thesis student at Kiepenheuer) and Oskar von der Lühe.

Fig 12. Rimmele and von der Lühe correlation tracking

Ray Smartt, who served as Deputy Director for SPO under Leibacher, organized three meetings concerning the design of an advanced technology, large aperture, reflecting coronagraph. He and Serge Koutchmy develop a 5 cm mirror advanced coronagraph (MAC I) using a super-polished silicon mirror as a demonstration of the technology needed. Keil, November and Bonaccini build a 20 mA spectral resolution filter using a Fabrey-Perot in front of the VTT's UBF. Work continued on Dunn's 61-actuator continuous phase plate adaptive mirror. George Streander, the optician at SPO, reground the mirror actuators, which arrived at SPO out of spec. Successful correlation tracker engineering runs at VTT begin. The correlation tracker permits the tip-tilt mirror to lock on solar granulation, eliminating the need for sunspots or other features to remove first order image motion, in early 1989 the tracker is commissioned for operational use and is incorporated in nearly every observing run. Also in 1989, HAO and NSO begin joint development of the Advanced Stokes Polarimeter (ASP) for use at the VTT. Bruce Lites of HAO, a former staff member at SPO, leads the effort.

1990-1999

NSO and the AF group at Sunspot submit a Large Aperture, Reflecting Coronagraph (LARC) proposal to the 1990 Astronomy Decadal Survey solar panel. Smartt and Koutchmy continued their reflecting coronagraph development with a 15 cm mirror advanced (reflecting) coronagraph (MAC II) and they developed a concept for a 55 cm reflecting coronagraph (MAC III). Johns Hopkins Advanced Physics Lab and the AF group installed a low polarization magnetograph in the Hilltop Dome on Sac Peak. A grant the AF group obtained from the Air Force Office of Scientific Research supported the JHU effort. The grant is also used to hire a group at SPO to operated the JHU instrument and interpret its data, and to fund a contract with U.C. Irvine to use the data to drive their models of active regions. 1990 also sees the installation of CHIRP, a high-speed video data collection system, for the VTT.

A new era of high resolution stokes polarimetry begins in 1991 with the installation of the HAO/NSO Advanced Stokes Polarimeter (ASP) at the VTT. The ASP becomes one of the most heavily used instruments for measuring vector magnetic fields in the solar atmosphere. The program to improve image quality by removing atmospheric seeing continued in 1992 with installation of the Lockheed 19 segmented mirror AO system (Acton and Smithson) at the VTT. By 1993 it was clear that The Lockheed AO system (Acton, Dunn) worked on pores only, because of scattered light and phase lock issues with the segmented mirror. The AO program begins testing of a continuous phase plate mirror and an LCD wavefront sensor. The design for MAC III (55 cm reflecting coronagraph) is completed.

Jacques Beckers becomes the NSO director in 1993 after John Leibacher steps down. John continues as the PI for the GONG program. Jacques increases the emphasis on the AO program and is strongly interested in a large aperture telescope with coronal capabilities. In 1994 many other changes are taking place at NSO, Bill Livingston and Jim Brault (both working in Tucson) retire and take emeritus positions. Bob Howard switches to a half-time position. Jeff Kuhn joins the Sac Peak staff and begins development of a series of Precision Solar Photometric Telescopes (PSPT) as part of the NSF sponsored Radiative Inputs from Sun to Earth (RISE) program. NSO/Sac Peak receives a subcontract from the Smithsonian Astrophysical Observatory to build a space qualified reflecting coronagraph for the SWATH mission (Space Weather and Terrestrial Hazards).

In 1995, Thomas Rimmele joins the NSO staff at Sac Peak. Thomas has been acting as a consultant on the AO and correlation tracing programs. Hartman wavefront tests show that wave front errors due to the entrance window often exceed image degradation due to seeing. Thermal control of the entrance window is implemented to reduce these errors. Develop of a Mark II correlation tracker for the VTT begins. The AF group at Sac Peak purchases a 91 actuator adaptive mirror for use with the Hartman sensor. Haosheng Lin also joins the staff and take on the responsibility of bring the PSPT on line. Testing of the Zurich Imaging Stokes Polarimeter (ZIMPOL I) begins at the VTT. NSO begins development of a digital library to provide access to its large collection of data. The Sac Peak spectroheliograms become part of the library along with Kitt Peak FTS and Vacuum Tower data. The SWATH coronagraph nears completion but unfortunately, the program is cancelled.

Beckers takes a sabbatical in 1996 to concentrate on design, costing and siting as well as possible descope options for a large aperture telescope. He names the effort CLEAR (Coronal and Low Emissivity Astronomical Reflector). In his absence Doug Rabin from the NSO/Tucson staff is appointed acting Director. NSO purchases high resolution Xedar CCDs (2K x 2K) for testing. The Mark II correlation tracker is installed in the VTT allowing large-scale image motion to be removed from observations on a routine basis. Rimmele performs the first successful AO experiments at the VTT in collaboration with the Laser and Imaging Directorate of the AF Philips Lab. They use a 127-element LCD wavefront corrector and Shack-Hartman wave front sensor. The AF group purchase two infrared Fabry Perot filters and uses them to make vector magnetograms at 1600 nm.

1997 sees the completion of a visitor center at Sac Peak. Dick Dunn wins the Hale prize for his work in solar instrumentation and observations. Dick retires the following year and takes an emeritus position. Telescope at other observatories, such as the Swedish and German vacuum towers, have benefitted from Dick's design work and consultation. The AF group tests two narrow band filter using dual Fabry Perot filters, one in the visible and one in the near IR (1200-1700 nm). The first PSPT telescope is deployed to Osservatorio Astronomico Roma and a PSPT data center is established as part of the RISE program at HAO. The CLEAR design and cost study nears completion and the CLEAR site survey shows the superiority of lake sites for stable seeing conditions.

NSO renames the Sac Peak VTT the Richard B. Dunn Solar Telescope (DST) in 1998. The CLEAR feasibility study is completed. Unfortunately, CLEAR never receives the strong community support needed to obtain NSF funding. NSO installs a second PSPT telescope on Mauna Loa and HAO will operate it. Beckers completes his term as director of NSO in Oct of 1998. Keil is appointed director, but delays starting his term until May of 1999. Rimmele serves as acting director in the interim. NSO jointly with the AF group, take on a project to improve the AF SOON telescopes by converting from spectrographs to tunable filters, the program is named ISOON (or Improved SOON). To facilitate the program, a room in the Hilltop facility becomes a test facility for ISOON optics.

1999 witnesses the first run of a low order AO system (20 degrees of freedom). The system achieved diffraction limited images in good seeing conditions. The AF purchases 150 mm Fabry Perot filters and the ISOON project begins testing and characterizing them at the Hilltop. NSO holds the first public meeting for an Advanced Solar Telescope (AST), a concept for a 4 m reflecting solar telescope, at the Chicago AAS meeting. AST heritage includes the MAC development and CLEAR studies. NSO submits the AST concept to the 2000 Astronomy Decadal Survey. A 3rd PSPT telescope begins operation at Sac Peak. Unfortunately Kuhn and then Lin leave NSO for positions in Hawaii and NSO interest in PSPT wanes. Keil works with AURA, NSF and NOAO to set the stage for removing NSO from NOAO. This is viewed as necessary in order to pursue AST funding successfully. The last quarter of 1999 is spent preparing NSO to leave NOAO.

2000 - 2017

2000 is the first year that NSO again reports directly to AURA and NSF. NSO renames AST to the Advanced Technology Solar Telescope (ATST), which removes a conflict with the NSF Astronomy Division also known as AST. AURA's Observatory Visiting Committee visits NSO and endorses the NSO program for the future. The Decadal Survey endorses the NSO and community plans for the ATST. AURA forms a Solar Observatory Committee (SOC) to provide NSO oversight. HAO announces plans to upgrade the Advances Stokes Polarimeter (ASP) jointly with NSO. Rimmele leads the submission of a NSF Major Research Instrumentation (MRI) to develop a high order AO system. The proposing consortium includes NSO, NJIT/BBSO (New Jersey Institute of Technology, Big Bear Solar Observatory), the AF group at Sack Peak and, the Kiepenheuer Institute for Solar Physics (KIS). NSF funds the proposal in 2001.

In 2001, NSO submitted an ATST proposal for design, development and site survey. NSO also formed an ATST Science Working Group (SWG) composed of both NSO and community members. NSO establishes a Site Survey Working Group (SSWG) and development of ATST site survey instruments begins. In 2002, NSF provides additional funding to the NSO base budget to begin the ATST design and development effort. The ATST site survey effort proceeds by first looking at weather and other statistics for about 72 sites. The SSWG recommends six sites for detailed observations and NSO deployed several site survey instruments. The Solar Image Motion Monitor (S-DIMM) is based on the well-established nighttime DIMM with the exception that a slit image of the solar limb is used as the target instead of a stellar point source. The instrument was developed by Jacques Beckers, and it measures overall seeing conditions at a site. The SHABAR (a contraction of the phrase Shadow Band Ranging), was a new instrument also developed by Jacques Beckers. SHABAR measures the height above the telescope where much of the seeing originates. A sky brightness monitor (developed by Haosheng Lin), dust monitor and weather station were also deployed.

Fig 13. The ATST seeing monitor. Visible are the two circular apertures for the S-DIMM, the linear array of six scintillometers for the SHABAR, and a Meade telescope.

In 2002, NSO established the ATST design effort, hiring a project manager and a team of engineers. Phase one of an ASP upgrade to a Diffraction Limited Stokes Polarimeter (DLSP) is completed. The prototype ISOON instrument is put into operation at Sac Peak. It produces high quality, full disk images and magnetograms. NSO conducts a successful test run of the high order AO systems. This is a critical step in demonstrating the technology to insure a large aperture solar telescope is available. ATST completes a successful conceptual design review in 2003. The DLSP enters phase II of its development. The Interferometric Bidimensional Spectrograph (IBIS) developed at Arcetri Observatory in Italy is installed in the DST. IBIS becomes the most used DST instrument. It permits rapid 2-D polarimetric imaging of the solar atmosphere at multiple wavelengths, allowing the development of vector magnetograms and velocity images.

NSO and its co-investigators at NJIT, U. Chicago, HAO, and the U. of Hawaii, submit an ATST construction proposal to NSF's MREFC (Major Research Equipment and Facility Construction) funding line in 2004. The proposal receives positive reviews and the review committee recommends it for NSF funding. The SSWG present ATST site survey results to the ATST project scientist. Together with the SWG, the project scientist recommends a site. NSO/AURA/NSF accept their recommendation in 2005 and Haleakala on Maui becomes the proposed site. In 2004, high Order Adaptive Optics (HOAO) becomes a user instrument at both the DST and BBSO primarily due to the efforts of Rimmele and Kit Richards. The DST staff employs HOAO during almost all DST observing runs. HAO/NSO deploys the DLSP at the DST fed by HOAO.

During 2005, the NSF director, following a cost review, elevates ATST to readiness status as part of the NSF MREFC program. This is a major milestone toward receiving funding. Rimmele conducted the first successfully Multi-Conjugate Adaptive Optics (MCAO) experiment at the DST. With MCAO one can correct seeing originating from multiple heights in the earth's atmosphere.

The 2006 NSF Senior Review is very positive for the ATST. ATST achieves a favorable Preliminary Design Review (PDR). NSF/NSO releases a Draft Environment Impact Statement (DEIS) for building ATST on Haleakala for public comment. Development of the Univ. of Hawaii and NSO Facility Infrared Spectro-polarimeter (FIRS) begins at the DST leading to a first engineering run. FIRS and HOAO permit diffraction limited full stokes polarimetry using multiple slits for rapid area coverage. HAO and NSO start the joint development of SPINOR (Spectral-Polarimeter for Infrared and Optical Regions). SPINOR and DLSP are both upgrades of the Advanced Stokes Polarimeter (ASP). Queens University Belfast and NSO begin development of the Rapid Oscillations in the Solar Atmosphere (ROSA) instruments, a set of six high-speed cameras operating in wavelength bands spanning the photosphere and chromosphere. At 30 frames/second ROSA will catch high-speed events in the solar atmosphere. HAO and NSO begin development of prominence magnetometer (PROMAG) for the 40 cm coronagraph in the ESF. HAO installs a Coronal Multi-channel Polarimeter (CoMP) in the Hilltop dome using the One Shot Coronagraph as light feed for joint HAO/NSO operations.

The National Science Board (NSB) tells the NSF Director he may include ATST in future budgets at his discretion and ATST enters the approval phase of the MREFC in 2007. Who knew MREFC had so many phases. Indeed, it seemed new phases were being invented because of ATST! NSO began queue-observing experiments using the DLSP at the DST in anticipation that queue observing would be the main mode at the ATST. SPINOR becomes operational at the DST. The ASP is decommissioned and NSO integrates SPINOR into the DST control and data system.

In 2008, COMP and the One-shot are used to search for Alfven Waves. The ATST SWG begins refining first-light use cases for the ATST. NSO dedicates a bench at the DST for MCAO experiments, a joint NSO/NJIT effort. Queen University Belfast conducts a ROSA commission run. The following year, U. Hawaii and NSO commission FIRS and make available to users. With IBIS, FIRS, SPINOR, DLSP, ROSA, Horizontal Spectrograph, UBF and HOAO, the DST is the World's best-instrumented solar telescope. Due to upgrades in its data collection system, up to eight large format (up to 4K x 4K) cameras can be operated simultaneously.

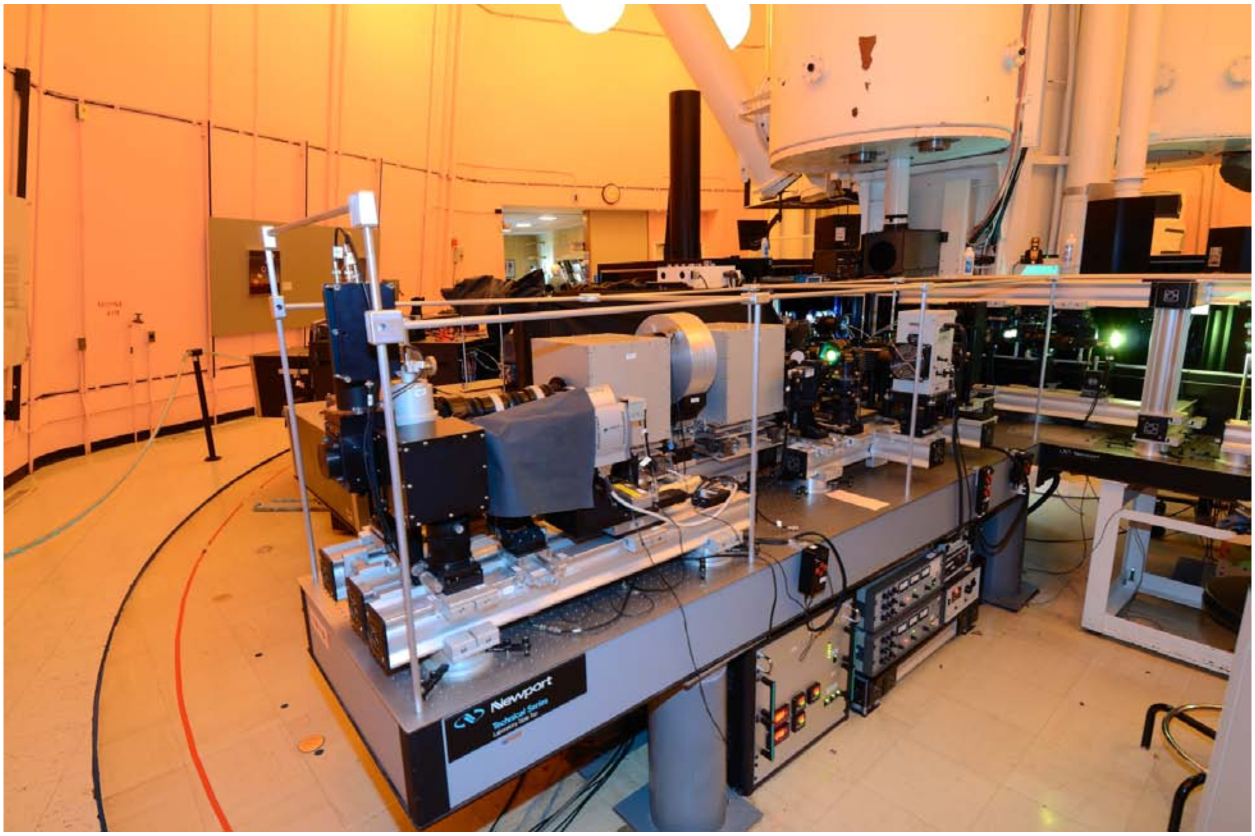


Fig 14. The observing table in the DST. IBIS is seen in the foreground and one of the two HOAO systems is see perpendicular to and just behind IBIS. The vertical black tower holds polarization optics and sits in front of the other HOAO system and feed the DLSP. Not shown are the table holding ROSA, FIRS, SPINOR, the horizontal spectrograph and the UBF. The DST table serves as a prototype for the DKIST observing room.

In 2009, the ATST holds a successful Final Design Review, which included reviews of management, cost, construction plans, and design. Following the review, NSO receives $146 m in American Recovery and Reinvestment Act (ARRA) funds for ATST constructions. In 2010 ATST moves into the construction phase. ATST project establishes vendor contracts for major ATAT sub-assemblies. NSO also received $1.4 M of ARRA funds for facility improvements and safety. NSO and BBSO also undertakes develop of a large format AO system (357 actuator) for the new BBSO 1.5 m telescope. This project serves as a stepping-stone for the 1900 actuator system required for the ATST. As part of developing and operating ATST, NSO must shut down its current operations at Sac Peak and Kitt Peak. As part of this process, NSO released a request for proposals for a new NSO headquarters, hopefully at or near a University to promote scientific interaction.

In 2011, several groups on Maui contested the ATST Conservation District User Permit (CDUP) for building on Haleakala and a court case ensued. Major ATST subsystem contracts at various vendors are well underway and progressing per plans. Staff scientist and visitors use SPINOR and IBIS for Hinode collaborations. NSO/AURA received and evaluated seven proposals for siting NSO HQ. A committee consisting of external and internal NSO scientists and administrators evaluated the proposals and the recommended the Univ. of Colorado Boulder as the final site. NSO established a MOU with KIS for development of the ATST Visible Tunable Filter (VTF). The HAO ProMag began operation at the ESF, but data proved difficult to calibrate and interpret. AURA/NSO finalized the University of Colorado Boulder (CU) as the site for the new NSO headquarters in 2012. ATST accepted delivery of the ATST M1 trial blank by the mirror vendor (Schott). ATST reorganizes its management structure in preparation for construction. Hawaii finally issues the ATST Conservation District Use Permit after completion of the court case. In Nov of 2012, ATST holds a groundbreaking ceremony and construction is underway. NSO appoints a data center scientist to begin developing plans to handle ATST data and distribution to the community and an ATST operations scientist to begin planning how ATST will be operated. Planning for NSO divestiture of Sac Peak and Kitt Peak begins. NSO starts organizing a transition team for shifting its headquarters to Boulder.

Fig 15. DKIST as it looked in March of 2017

In Aug of 2013, Keil Steps down as director. Valintin Martinez Pillet is appointed NSO director. ATST site preparation is fully underway and vendors are well along in developing concepts for ATST sub-assemblies. Staff members begin moving from Sunspot to Boulder. NSF establishes a new 10-year cooperative agreement with AURA for NSO operations intended to cover development and early operation of ATST. In early 2014 the ATST is renamed the Daniel K. Inouye Solar Telescope (DKIST). Keil retires in Aug of 2014 and accepts an emeritus position. NSO closes the ESF in 2015 and HAO removes ProMag. 2016 and 2017 see DST operations turned over to NMSU. NMSU received a grant from NSF to develop an operations model and consortium to operate the DST. NSO holds a final Sac Peak workshop in their long series of NSO/Sac Peak workshops in Aug of 2017. This paper and the following reminiscences were part of that workshop. As of 2018, NSO continues to maintain a very small staff at Sac Peak.

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