

Inexpensive Global Network of Robotic Solar Storm Monitors

Technical Proposal:

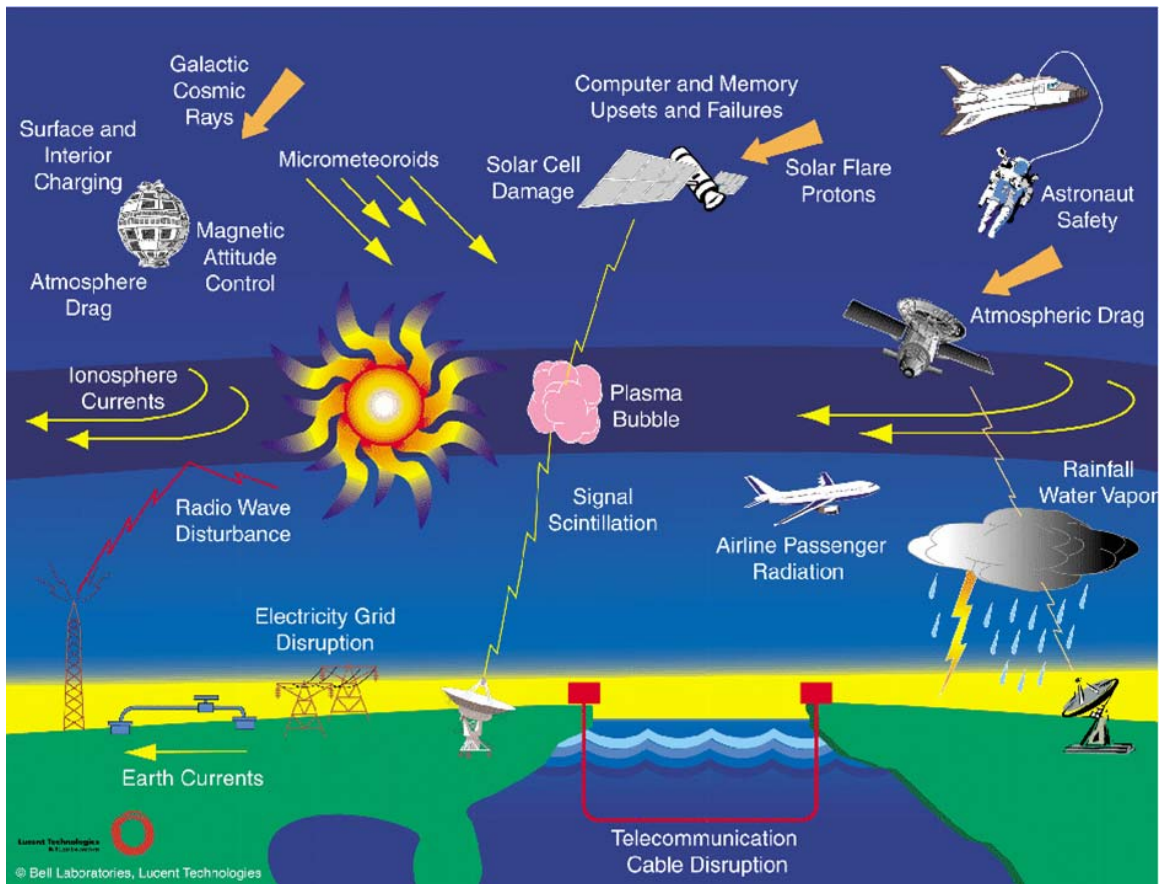
A. Overview

Big Bear Solar Observatory (BBSO, see bbsol.njit.edu) has long experience in “space weather” observations and forecasting. BBSO is operated by the Center for Solar-Terrestrial Research (CSTR, see solar.njit.edu) at New Jersey Institute of Technology (NJIT). NJIT is the home institution of the AGU journal called Space Weather (see agu.org/journals/sw/).

BBSO has built robotic telescopes, which can be remotely monitored, for nighttime observations. BBSO is presently operating a global network of H α telescopes to monitor space weather. A spin-off company, HelioSynopTek (HST), plans to utilize these experiences to build and deploy a global network of robotic telescopes to monitor and provide Air Force customers at Offutt AFB, and others, real-time data on pending space weather events, as well as data for Air Force experts to sharpen and utilize their forecasting models. The robotic network of Solar Storm Monitors (SSM) would provide all data, and more, that are currently provided by the Solar Observing Optical Network (SOON). The robotic SSM network will have two primary advantages over the SOON. First, the robotic SSMs would be vastly cheaper to operate. Second, since they are controlled remotely, they would be placed at astronomical sites, which are characterized by clearer skies than the SOON sites.

In Phase I, one skeletal robotic SSM would be built and tested by HelioSynopTek. In our view, the most difficult component of a SSM will be the robotic control. This is one key expertise being spun-off from BBSO to HST. Phase I will cost \$98 K and be completed within nine months.

Eruptive events on the Sun cause what is broadly called space weather. The figure below clearly illustrates the wide variety of space weather effects that can interfere with Department of Defense (DoD) and civilian assets. Almost all of these effects are directly due to the Sun, or disturbances originating from the Sun. Solar energetic particles (SEPs) effect spacecraft through solar cell damage, computer and memory upsets and failures, and surface and interior charging. Such particles also represent a significant radiation hazard to astronauts and airline crew on polar flights. Polar shortwave radio communication can be interrupted for days due to Polar Cap Absorption from SEPs. Solar X-rays cause sudden changes in the atmospheric drag on orbiting spacecraft, as well as ionospheric disturbances that effect shortwave communications and cause scintillation of satellite signals, and so on. During a flare, the solar radio flux can be 10,000 larger than the pre-flare reading, therefore the Sun can interfere with GPS and wireless communications. Such a flare swamped NJIT’s radio telescope on December 6, 2006 at 3:45 PM EST.



In order to make reliable predictions or warnings with the maximum lead time, it is necessary to start at the source of the disturbances, the Sun. A single event, may be spread over 2-3 days; the radiation effects occur almost immediately, the particle effects occur over hours to days, and the magnetic effects are delayed by 2-3 days from the start of the event. One or more of the ingredients, radiation, particles, or magnetic clouds, may be deceptively weak while another reaches dangerous proportions, and only through long experience can one hope to recognize the signs of a developing threat in time for a meaningful warning.

Necessary strategies for reducing the impact of these effects should rely chiefly on early warning, or prediction of impending events, so that satellites can avoid risky maneuvers, astronauts can seek safety, polar flights can be rerouted, and communications can shift to more “hardened” lines of communication. Equally important is the need for commanders to know that communication difficulties they may experience are the result of natural effects, and not the actions of an adversary. Another mitigation strategy is to use the knowledge gained in space weather studies to the design of satellite systems so that they will survive the largest event expected over their design lifetime.

At present, much of the efforts rely on detecting such events when they reach near-Earth satellites, like ACE, and the data are used to estimate the length of the event. The Sun is monitored for space weather storms, but not at all times and not with measurements needed to detect solar storms.

B. Space Weather Measuring and Forecasting Experience at BBSO

At Big Bear Solar Observatory (BBSO), we have unique experience and capabilities to actually forecast the terrestrial impact of such events, hours to days before they reach Earth:

1) From BBSO, we have been monitoring some kinds of the events for many years with a global network of telescopes requiring operators, and issuing space weather storm warnings when appropriate. Therefore, we can even predict effects of solar eruptions usefully far in advance of their occurrence, rather than “now-casting” with an estimate of duration.

2) We have written and tested software for flare detection, and other solar eruptions. The software uses neural networking in the frame of Supporting Vector Machine, and learns how to detect flares from a sample input.

3) We have designed and build small, robotic telescopes for nighttime observations. These nighttime telescopes are comparable in physical size to a SSM, but the SSM’s will be slightly more complicated to control.

It is these experiences, 1)-3), that will be transferred to HST along with the BBSO employees who accomplished the three tasks. Of course, other BBSO staff will be available in an advisory capacity.

The HST team plans to build a global network of robotic telescopes to monitor the Sun and release automated real-time reports of significant eruptions with near real-time interpretation. This would be vastly less expensive and a more capable replacement of the outdated Air Force SOON system. With our long experience in forecasting, coupled with our experience in building robotic telescopes, operating global networks, providing data in real-time to a community, and with the addition of state of the art artificial intelligence detection software, BBSO spin-off HST is uniquely positioned to fill this essential niche.

We anticipate that the full Solar Storm Monitor (SSM) prototype will cost about and additional \$750 K, and \$600 K for each clone. Of course, we will have a much better estimate of the full-up prototype and clones (Phase II) after completing Phase I. For the project to be fully functional, our goal is to deploy a fully operational three station network in three years, costing roughly \$2.0 M, with three more stations over the following two years to have redundant coverage in case of cloudy weather or hardware problems at one station. The SSMs can be sited at solar observatories chosen for image quality, rather than at military bases chosen because there are personnel. The operating costs will be about \$300 K per year, all of which is an order magnitude less expensive than the proposed ISOON. Phase I of the project is described in detail in the next section.

C. Phase I: Solar Storm Monitor Prototype

The goal of Phase I is to design, build and test a bare-bones version of the Solar Activity Monitor (SSM) prototype to demonstrate the feasibility of the full prototype – all within

nine months. This includes a full-disk H α in a simplified light feed into a cargo carrier modified observatory. All of the hardware is commercially available or already in BBSO. The light feed is done by a small turret with an aperture about 5cm.

Budget	
Insulated Shipping Container with Power & AC (SSM Shelter)	\$ 8 K
Support Structure (Concrete Foundation, Reinforcements, etc)	\$25 K
Feasibility Turret	\$10 K
Tracking System	\$10 K
Design Full SSM and Supervise H α Prototype	\$45 K
Total Phase I Budget	\$98 K

The most difficult part of Phase I will be the implementation of robotic control. We know this from our experience building nighttime robots. However, the HST personnel understand the issues involved and the prototype will be the ideal testbed.



For the prototype and the first full SSM, we selected the previous site of the Taiwan Oscillation Network (TON) shown in the figure above. We can make use of the TON foundation to erect the 5-meter high telescope support stand built from two segments of

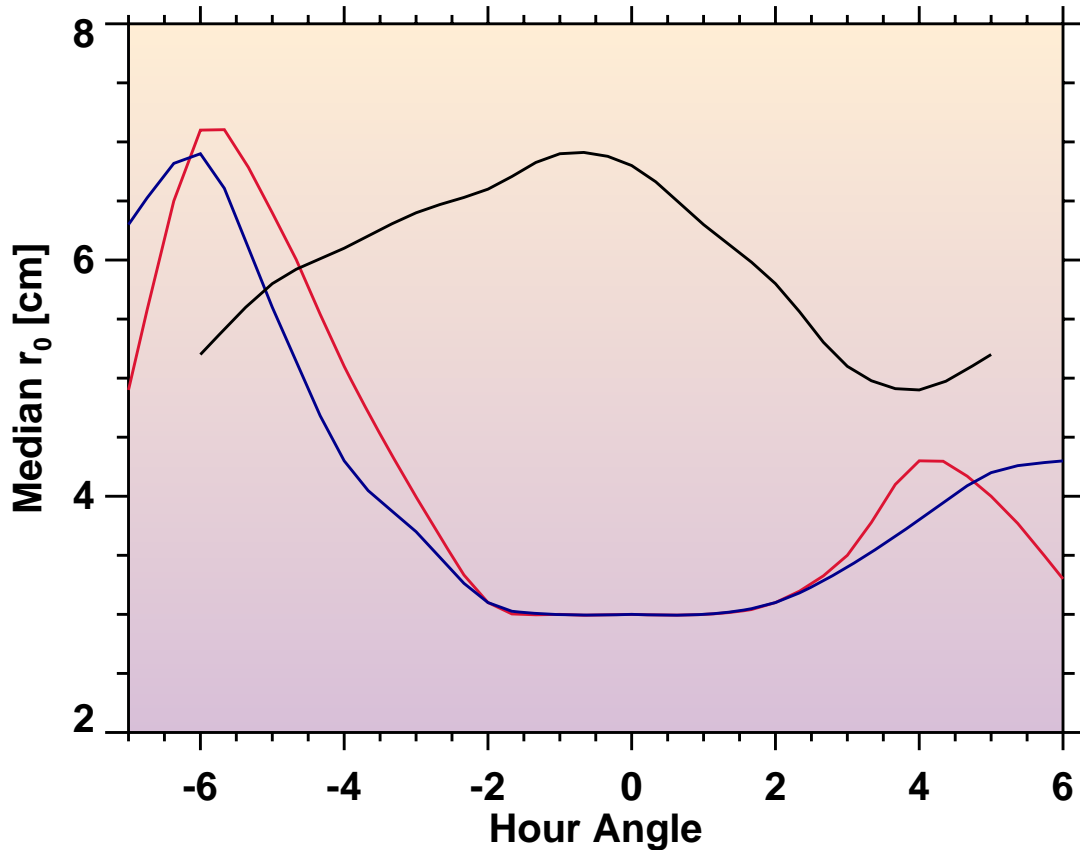
prefabricated reinforced concrete drainage pipe with a 2-meter diameter. The concrete segments will be attached to the foundation by a framework of steel I-beams. The turret adds another meter to the height of the telescope aperture, which will be sufficiently high to see the Sun at noon above the observatory building even in the winter months. Thus, unobscured observations are enabled from sunrise to sunset. The optical instruments will be located in a modified 20 ft by 8 ft cargo container (for the location see area outlined by the yellow caution tape shown in the above figure). This is the same type of instrument enclosure that has been successfully used for the GONG global network telescopes. The cargo containers will be painted with titanium oxide to minimize the heat load in the summer months. The walls are insulated and a heating and air conditioning system will keep the instrument environment at a constant temperature.

During rain or snow, the telescope control software will move the entrance window into a secure position. The telescope is using a turret system, which allows for a very compact instrument envelope. Simplicity is one of the SSM design goals. All of the optical and mechanical components are readily available. The telescope output and operation can be remotely monitored from a notebook computer. From this computer, an interested party can examine data in real-time, as well as look at the SSM in operation. The prototype can be remotely opened and closed.

BBSO will provide all the required filters for the prototype, including the $H\alpha$ Lyot filter, which the observatory has on-hand. Further, BBSO will provide the control computer and all our fully operational analysis software to provide one (processed) $H\alpha$ image every minute with automatic flare/filament eruption detection software that can automatically make cadence five times faster. The images from this robotic system will be provided to customers in real-time.

BBSO is the ideal site for the SSM prototype. In the National Solar Observatory (NSO) site survey for the next generation national solar telescope, the seeing (r_0 , a measure of the largest aperture telescope that would be diffraction limited at that site) vs. time of day is shown in the figure below for the three finalists.

In an era when high resolution telescopes, like BBSO's 1.6 m off-axis telescope (the NST with a hardware cost of about \$4.5 M), are coming to fruition, it is critical to have high quality full-disk synoptic data to provide context for the high resolution data, especially in predicting space weather and probing its origin. The NST will supplant BBSO's 65 cm high resolution telescope, along with BBSO's synoptic telescopes. The SSM system with its upgraded synoptic capabilities will enable the NST to reach its potential. The removal of BBSO old telescopes has left a wealth of hardware (optics, support structures, etc.) that will be used for the SSM prototype in Phase I. In Phase II, many of these items will be replaced by newer, more scientifically viable hardware, which is essential to reliably providing the highest quality data.



The black line is for BBSO and the other two lines are for the Halekala (red) and LaPalma (blue), as measured by NSO's dual image motion monitor. BBSO is characterized by steady good seeing all day long most every day over the two years of site survey data. This makes BBSO the ideal U.S. site for collecting space weather, synoptic data. The data also justify a high resolution solar telescope in BBSO.

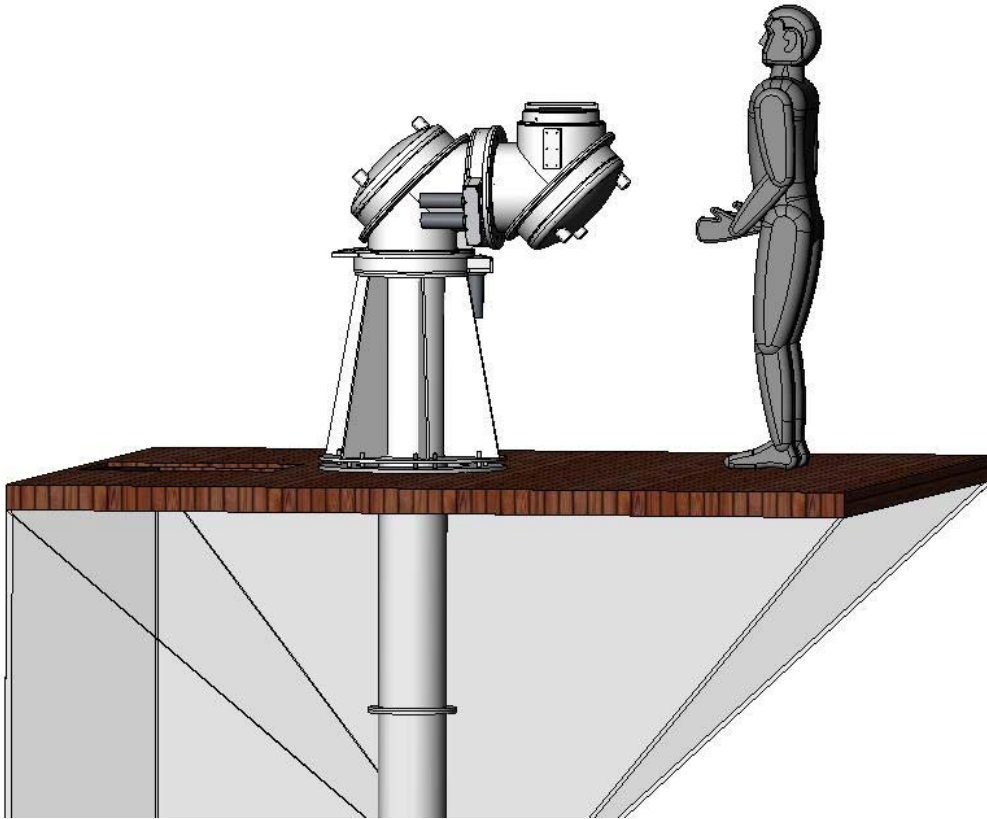
BBSO has been operating a global $H\alpha$ network for several years. This includes having developed all the image processing and automatic filament eruption detecting software. In addition, we have built a fully robotic synoptic telescope for observing earthshine to measure the Earth's albedo; a clone of the prototype is being deployed in the Canaries at this writing. Robotic means remote manual operation to open, but all other aspects are fully robotic. We have found that this type of robotic telescope minimizes complications in design and problems of cost. Finally, hardware choices were made based on our experience in designing and building $H\alpha$ telescopes and digital vector magnetographs. We need and can build requisite sub-arcsecond resolution with inexpensive, reliable and automated hardware. The SSM will be constructed with all off-the-shelf items, as were the semi-robotic earthshine telescopes.

BBSO has extensive experience in providing synoptic data products to the solar community and beyond. These data are used by us, and others to provide near real-time space weather forecasts. As well, BBSO synoptic data have been used

by many in basic research projects around the world, such as many Ph.D. theses.

C. Phase II: The Full SSM

The first full SSM will be based on our long experience in building synoptic telescopes and semi-robotic telescopes for our global networks. All components of each SSM are easily repaired/replaced because they are commercially available and will utilize control and analysis software that we developed and is fully operational in our existing synoptic systems. Until recently, one essential component of the prototype was not commercially available, and that is a world-class reliable turret system. The turret is a copy of the new and successful Swedish Solar Telescope (SST) – at present, the world's most capable telescope for high-resolution studies of the Sun. Stockholm's Digitalmekanik, the manufacturer of the SST, is marketing a miniature, cost-efficient version of the SST with an aperture of 25 cm, which is ideally suited for a synoptic telescope like the SSM. The SSM would be fed by light from an evacuated turret system (see figure) elevated 5 m above the ground to ensure the highest quality light signal. The evacuated turret would reach vertically above the ground layer seeing. A system of flip mirrors, based on currently operating ones at BBSO, would alternatively direct the light exiting the turret to full-disk $H\alpha$, Vector Magnetograph (which includes white light) and CaK systems. This prototype would provide state of the art measures of the fundamental indicators of space weather changes. A schematic view of the top of the turret is illustrated in the figure below.



In Phase II, HST and BBSO will propose to build and deploy a global network of near-robotic, synoptic telescopes that will provide a thorough spectrum of real-time, full-disk images of the Sun, which are essential in studies of space weather. These telescopes will be simple, inexpensive and made from off-the-shelf items. In baseline operation, one-arcsecond pixel resolution images will be in $H\alpha$ every minute. Cadences would automatically increase in the event of a flare or filament eruption. Further, the SSM (Solar Storm Monitor) telescopes would provide vector magnetograms every few minutes. The magnetograph provides white light images with the same cadence. As well, full disk CaK images will be available with this cadence. Each kind of measurement provides unique and essential information on solar events that drive space weather. $H\alpha$ is essential in the tracking of filaments and flares, while the vector magnetograms elucidate the structure of active regions. All of these data will be made easily available in near real-time.

D. Some Details of the Phase II SSM Prototype:

The full prototype would be fed by light from the aforementioned commercially available evacuated turret system to ensure the highest quality light signal. The turret would reach above much of the boundary layer and be further improved by a commercially available tip/tilt system, which is the first order adaptive correction. The 25 cm aperture of the turret system would be stopped down to 15 cm, which is about twice the annual mean Fried parameter, r_0 , of the BBSO at the height of the turret. The diffraction limit of the stopped down system is about 0.7 arcseconds. The stop-down is made to enable us to make full disk $H\alpha$ and magnetograms with the BBSO Lyot filters. With large Fabry-Perot filters, it would be possible to take full advantage of the 25 cm aperture (0.4 arcsecond diffraction limit). However, this is probably overkill (better spatial resolution than is currently available for any synoptic system) for space weather work, and would make the system much more expensive. If one wants much higher resolution, one should think of telescopes like the NST, which have to sacrifice field-of-view for resolution because of thermal issues.

BBSO will provide all the required filters for the prototype, including the $H\alpha$ and magnetograph Lyot filters, which the observatory has on-hand; therefore filters are not included in the cost estimate. Further, BBSO will provide the control computer and all our fully operational analysis software to provide one (processed) $H\alpha$ image every minute with automatic flare/filament eruption detection software that can automatically make cadence five times faster. The images from this nearly robotic system will be provided to customers in real-time. The estimated prototype budget is below. This Phase II budget will be naturally sharpened during the Phase I manufacturing.

Budget	
25 cm TelescopeTurret System	\$150 K
Optics and Flip Mirrors	\$40 K
Large Format (2K by 2K) Fast Camera for $H\alpha$	\$40 K
Magnetograph Optical Components	\$25 K
Tip/tilt System	\$25 K
Optical Support Components	\$20 K
Data Archive System Updated in Near-Real Time	\$10 K
Three Person Years Labor including SSM design (Loaded Salaries)	\$440 K
SSM Prototype Budget	\$750 K

The first building block of the SSM is an $H\alpha$ full-disk imager based on the experience of the very successful, but now retired Singer full-disk telescope at BBSO. The SSM telescope will deliver a well-defined focal plane and pupil

image, which are the starting points for any subsequent scientific instrument. Thus, allowing for flexibility in the optical set-ups and providing an easy upgrade path for the lifetime of the instrument.

The H α Lyot filter that is currently being used will be replaced with a Zeiss Lyot filter that thus far has been reserved for high-spatial resolution observations on the now retired 65 cm vacuum reflector. This Zeiss filter is computer controlled and enables automated spectral line scans. A bandpass of 0.05 nm or 0.025 nm can be selected depending on the research program. This leads to a moderate spectral resolution of about 25,000. The transmission of the Zeiss Lyot filter is about 30% higher compared to the old system. The transmission will be further improved by about 40% using a narrow band (0.5 nm) ion-assisted deposition interference filter manufactured by Barr Associates, as the prefilter for the birefringent filter. The bandpass of the prefilter is sufficiently narrow to suppress false light but wide enough to permit line wing measurements.

The improved transmission characteristics of the filter system, the larger aperture of the telescope, and a better quantum efficiency of the CCD camera system ultimately will lead the way toward a large-format, 4k by 4k pixel detector. The exposure times will be similar to the existing system corresponding to about 40 ms at H α line center. High-cadence full-disk observations with better than a 1 arcsecond spatial resolution will be the cornerstone of the SSM. Since the expected cadence for the synoptic observations is about one image every minute, or one image every 10 seconds for flare studies, a data acquisition rate of one frame per second is adequate. This eliminates the search for fast frame rate CCD cameras and allows us to choose science-grade, large format CCD camera systems marketed for the high-end amateur astronomy market. These camera systems are extremely cost-effective and have a variety of characteristics that make them ideally suited for synoptic solar observations. These detectors are commercially available for about \$40,000 (see the Alta U16 system from Apogee (<http://www.ccd.com>)). However, for Phase I, we will use our existing 2k by 2k pixel CCD camera system to minimize the Phase I cost.

The Phase II SSM will have the following specifications:

- 1) 25 cm effective aperture for high-cadence and large-format full-disk images and full-disk vector magnetograms.*
- 2) The telescope is sufficiently flexible to allow future upgrades.*
- 3) The SSM will maintain and expand a decade-long record of full-disk observations at BBSO.*
- 4) Capable of full-disk vector magnetograms with spatial resolution (before AO and camera upgrades) of 0.7 arcseconds at 600 nm to complement the H α (and other) full-disk observations and provide a comprehensive data set for space weather research and forecasting.*
- 3) The SSM will increase and simplify the access to the scientific data products for Air Force customers.*

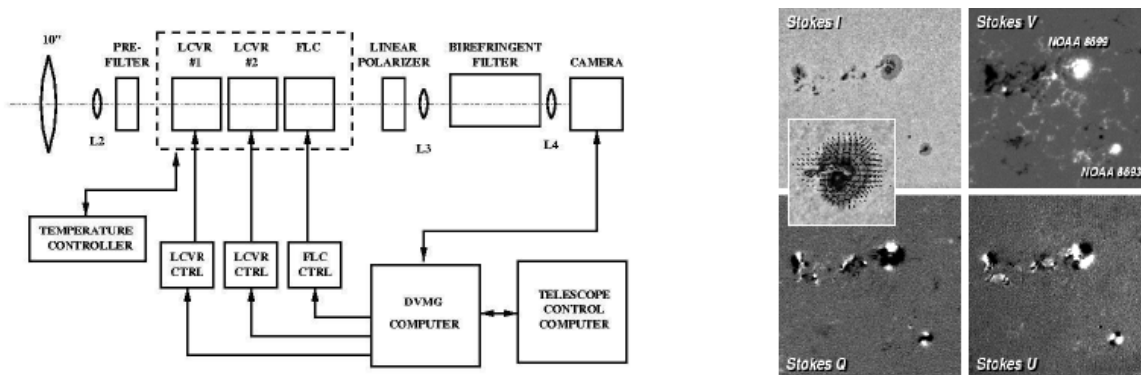
The most challenging design problem derives from the small entrance aperture (30 mm) of the Zeiss H α filter. In detail, we want to image a relatively large FOV of about 0.5 degrees encompassing the whole Sun with good image quality. However, it should be noted that the diffraction-limited resolution of the H α telescope is somewhat smaller than the image scale for the 4k by 4k pixel detector. Nonetheless, the SSM is a diffraction-limited telescope, and full advantage of this would come from adaptive optics and later from larger format cameras. To carefully consider the other possible problems arising from the Zeiss filter, we note that there is another problem resulting from the variation of the passband with the angle of incidence across the filter. The beam has to be slow enough so that the change in retardation compared to normally incidence rays will not affect the 0.025 nm passband of the Lyot filter. Some of these problems can be mitigated by a field lens, which is inserted in front of the focal plane of the Zeiss filter in a telecentric configuration. A specially designed Cooke triplet can then be used to remove the remaining aberrations, i.e., first-order longitudinal and lateral color, and the five monochromatic third-order Seidel aberrations. The chromatic aberrations are not that important for the H α channel and the corresponding degrees of freedom can be used to improve the lens design for the monochromatic aberrations. Another option would be an intermediate pupil stop. This is of particular importance for the magnetograph (see the next paragraph), because the Zeiss filter and polarization optics can only accept limited incident angles, since retardation varies across the filter with the square of the incidence angle. We have learned from our colleagues in Nanjing, who repaired one of our Zeiss filters, that their experience and review of our designs has led them to argue that our pupil stopdown will have to be to 15 cm for the full disk magnetograms from SSM. This is why we have quoted a diffraction limit of 0.7 arcseconds at about 600 nm for full-disk magnetograms from SSM. At any rate, the problems arising from the small entrance aperture of, and beam incidence to the Zeiss filter are straightforwardly soluble. *The H α data products are:*

- 1) *4k by 4k pixel H α full-disk images with a cadence of one minute.*
- 2) *4k by 4k pixel H α full-disk dopplergrams and line scans with a cadence of 30 minutes. These data are especially important in the prediction of filament eruptions.*
- 3) *High-cadence (once every 10 s), 4k by 4k pixel H α full-disk images for flare studies. An automated flare detection algorithm has been developed with support of an NSF ITR grant (to develop leading edge image reconstruction) that will be implemented in the SSM control system.*
- 4) *All data will be carefully calibrated including limb darkening subtraction to enhance image contrast. The full-disk data are compiled into daily, low-resolution quick-look movies and full-resolution movies featuring flares, Moreton waves, filament eruptions, and other energetic events.*
- 5) *Daily maps of flow fields are computed providing information on differential rotation, meridional flows, and proper motions in active regions.*

6) *Since many science objective do not require high-precision photometry, data compression is used for the bulk of images.*

The Digital Vector Magnetograph (DVMG) system has been one of the BBSO “workhorses”. Its design was presented in detail in the PhD thesis of then NJIT student Thomas Spirock in 2001, who did his thesis under the supervision of Goode (PI here). He developed this instrument supported by the AFOSR Graduate Fellowship Program, and received his Ph.D. in Electrical and Computer Engineering. Thomas was also the key architect of the robotic telescope in Big Bear and will be involved in this project.

The DVMG analyzes the polarization state of light, i.e., its intensity (Stokes-I and the default white image), the circular polarization (Stokes-V), and the linear polarization (Stokes-Q and -U). Two types of magnetograms are provided by the SSM: longitudinal (line-of-sight) magnetograms and vector magnetograms of the full Stokes-vector including the transverse component of the magnetic field. The FOV of the current system is about 300 by 300 arcseconds with an image scale of 0.6 arcseconds per pixel. The typical cadence is one minute. The figure below shows a schematic of vector magnetograph system and the components observed under the old system, where “LC” means “Liquid Crystal”. The SSM magnetograph will yield higher quality magnetograms than shown below.



Much of this design can be carried over to the SSM telescope for full-disk observations. Again, since we use a Zeiss filter in the Ca 610.3 nm line, the same optical considerations and limitations apply as in the case of the H α full-disk imager. The light would be fed directly from the telescope to the magnetograph, and we insert a computer controlled flip mirror to direct the light to the H α imager. In principle, a dichroic beamsplitter could be used, but it would introduce a strong astigmatism. Time-sharing seems to be the better choice in this case (this would also include an hourly CaK feed). The existing polarization optics consisting of a ferro-electric and two nematic liquid crystals can be used without modification. Thus, minimizing system migration and integration time. The only design effort is related to an appropriate re-imaging optics. Of course, other wavelengths can be used straightforwardly, but experience has led us to prefer 610.3 nm at BBSO.

The major change of the DVMG system involves its detector system. We purchased a Cooke PCO.2000 CCD camera. This 2048 by 2048 pixel CCD camera has a peak quantum efficiency of 55%, which is more than three times as large as the current system. In addition, it has 14-bit digitization, an improved signal-to-noise ratio, thermo-electric cooling, and a data acquisition rate of 10 frames per second. Integrating this camera into the DVMG system allows an upgrade to full-disk imaging with an image scale of 1 arcsecond per pixel. *The vector magnetogram products are:*

- 1) *2k by 2k pixel full-disk longitudinal magnetograms with a cadence of one minute.*
- 2) *2k by 2k pixel full-disk vector magnetograms with a cadence of four minutes.*
- 3) *2k by 2k pixel full-disk continuum filtergrams with a cadence of one minute.*

E. SSM Clones – The Inexpensive Global, Space Weather Network:

After successful testing and operation of the SSM prototype, HST would manufacture multiple versions of the turret system, and then deploy and install them around the world. The Canaries and Learmonth would be initial targets so as to give uniform global coverage at excellent sites with extended periods of clear skies and experienced observing teams. BBSO would also provide the optical feed to on-site Lyot (or Fabry-Perot) filters (or BBSO could loan some of its several Lyot or Zeiss filters, which are of less use to BBSO with the advent of the NST and our Fabry-Perot filters for polarimetry) and camera systems. BBSO would also maintain the SSM's, and work to ensure that the information is supplied to customers in a useful format in near real-time. Further, BBSO would collaborate with HST and its customers in the interpretation of the data.

F. Management Plan and Project Milestones

The overall project responsibility in Phase I rests with PI Goode who will benefit from the experience of the BBSO and HST teams. The experienced team of BBSO and HST researchers, computer experts, and mechanical and optical engineers who have been intimately involved with various instrumentation projects over the years. The Phase I is well-defined, low-risk, and has a realistic nine month time-horizon.

The project is located both at NJIT/CSTR and BBSO. The work efforts at NJIT/CSTR will be directly supervised by HST. Frequent visits to BBSO are planned to coordinate the work at both project locations. Both NJIT and BBSO have video-conference facilities, which will be used on a bi-weekly basis to foster the collaboration between team members at both locations and keep everyone up-to-date on the progress of the project, as well as to ensure it remains on schedule. HST will schedule the local contractors and makes sure that the building modifications are done on-time and according to local building codes, as

well as leading the system integration efforts of the mechanical components at BBSO.

Francine Goode (CEO of Heliosynoptic) has long experience in procurement for BBSO. She spend four years as a successful fundraiser for BBSO during which time she learned all aspects of BBSO operation as she raised foundation funds to purchase hardware and support observatory operations. The SSM project management and development will follow the already successful BBSO project that has built and deployed inexpensive, but sophisticated robotic telescopes for nighttime observations.

Even though the SSM is a challenging instrumentation project, a graduate student can play a crucial role in the instrument development in Phase II. Many CSTR graduate students and alumni have developed substantial parts of instruments and subsequently used these instruments for scientific projects. We intend to follow this successful path and a full-time graduate student.

CURRICULUM VITAE

PHILIP R. GOODE

Address:

Department of Physics
New Jersey Institute of Tech. (NJIT)
Newark, New Jersey 07102

40386 North Shore Lane
Big Bear Solar Observatory (BBSO)
Big Bear City, California 92314

Phone and E-mail:

Work:(973)596-3565
Home:(908)232-0246
pgoode@bbsso.njit.edu

Work:(909)-866-5791x20
Home:(909)-866-5791x32

Education:

Ph.D. (Physics), February 1969
Rutgers, The State University

A.B. (Physics), June 1964
University of California, Berkeley

Present Positions:

1997- Director, Big Bear Solar Observatory, NJIT
Director, Center for Solar-Terrestrial Research (CSTR), NJIT

1994- Distinguished Professor, Physics, NJIT

1996- Visiting Associate, Physics, Caltech

Research Interests and Experience:

Sun's interior and atmosphere; magnetic fields; helioseismology; climate studies.
Over 200 publications.

Director of BBSO and CSTR, which has more than 10 Ph.D. students. Among 24 current and past students and postdocs, 10 have moved on to faculty/national center tenure track positions.

Leading the project to build BBSO's 1.6 m clear aperture, off-axis solar telescope (world's largest aperture) that will have its first light in 2006. Its light will feed our high order adaptive optics system, which in turn will feed our next generation, Fabry-Perot based, visible light and near infrared polarimeters. Building robotic telescopes for synoptic observations. Built robotic, synoptic nighttime telescopes. Operating global network to measure H α for space weather studies.

Recent Committees:

2001: Augustine Panel (Blue Ribbon Panel)
2006-2007: NASA Lunar Architecture Subcommittee-Science & Return to Moon
2005-2008: AAS Joseph Weber Award for Astronomical Instrumentation Comm.
2005: NASA: Senior Review
2003: NASA: Senior Review
2001-2002: Solar and Space Sciences Survey Committee
2001: NSF-AST: NOAO Management Recompetition Panel
2001: NSF-ATM: HAO Review
1999-2000: Solar Panel, Astronomy and Astrophysics Decadal Survey
1999: NSF-AST Committee of Visitors

Awards and Honors:

Fellow: American Physical Society
Minor Planet 11790 Goode
SERC Senior Fellow: University of Cambridge
Tau Beta Pi: NJIT
Three Varsity Letters: Cal, Berkeley

Society Memberships:

American Physical Society (Fellow)	International Astronomical Union
American Astronomical Society	Sigma Xi
American Geophysical Union	Big C Society
American Association for Advancement of Science	

Four Recent Publications

Evidence of Rapid Flux Emergence Associated with the M8.7 Flare on 2002 July 26, Wang, H., Qiu, J., Jing, J., Spirock, T.J., Yurchyshyn, V., Abramenko, V., Ji, H., Goode, P.R., 2004 *Astrophysical Journal* 605, 931-937.

The Sun from Big Bear in: The Future of Small Telescopes in the New Millennium II, T. Oswalt (ed.), *Astrophysics and Space Science Library* 288, Kluwer Academic Publishers, Dordrecht, Goode, P.R., Denker, C., Wang, H., 2003, 137-154.

Signature of an Avalanche in Solar Flares as Measured by Photospheric Magnetic Fields, Abramenko, V.I., Yurchyshyn, V.B., Wang, H., Spirock, T.J., Goode, P.R., 2003, *Astrophysical Journal* 597, 1135-1144.

Spaceweather Research at Big Bear Solar Observatory. Gallagher, P.T., Denker, C., Yurchyshyn, V., Spirock, T., Qiu, J., Marquette, W.H., Wang, H., Goode, P.R., 2001, *Annales Geophysicae* 20, 1105-1115.

RESUME

FRANCINE B. GOODE

Address:

HelioSynopTek
Center for Solar-Terrestrial Research
New Jersey Institute of Tech. (NJIT)
Newark, New Jersey 07102

Phone and E-mail:

Work: (973)596-5376
Home:(908)232-0246
fran@bbso.njit.edu

Education:

Columbia University, M.A., 1975
Hunter College, B.A., 1965

Professional Experience:

HelioSynopTek--CEO--2007

Educational Consultant--2004-2007

NJIT-- Asst Director of Development--2001-2004

-Fund Raising for BBSO

NJIT--1977-2001

Director of Testing

Assistant Director of the Counseling Center

Admissions Counselor