REU Site: An Interdisciplinary Undergraduate Research Experience in Solar and Space Physics
The University of Colorado and its Consortium Partners

PROJECT DESCRIPTION

1. Overview

1a. *Objectives*

The Laboratory for Atmospheric and Space Physics at the University of Colorado, and its associated departments, proposes to lead a consortium of Boulder-based research and academic institutions (including NCAR's High Altitude Observatory, NOAA's Space Environment Center, and the Colorado Research Associates) to establish a five-year REU site program in solar and space physics. The goal of this program is to introduce students to the interdisciplinary nature of solar and space physics (as a model for integrated research) and to a competitive research environment. This program will allow them to develop confidence as researchers and scientists, and will generate close communication among participants and between participants and the science mentors.

The REU site program would begin with a two-week undergraduate summer school in solar and space physics, developed in partnership with the Center for Integrated Space Weather Modeling (CISM) and modeled on CISM's highly successful graduate summer school. The Boulder summer school will take a 'whole system' approach to studying the Sun and its interactions, utilizing the talents of scientists from across the consortium to give the students an 'end-to-end' research experience in solar and space physics observations, data analysis and modeling. The summer school would be required for all REU site undergraduates, but would be open to any qualified undergraduate interested in participating, including CISM undergraduates.

After the summer school, 12 REU undergraduates (8 supported by NSF and 4 supported by consortium members) would participate in a 6- to 8-week research experience involving science projects across the institutions and spanning a wide range of topics from helioseismology to spacecraft operation anomaly analysis. Each student will be assigned to a project team that consists of two undergraduates and a minimum of two science mentors. Undergraduate projects proposed by consortium science teams will be competitively vetted in the spring, with the successful science teams receiving a 2-day training session on working with and teaching undergraduates.

Students from undergraduate institutions across the country, some recruited through CISM and through NASA's Minority-University Space Interdisciplinary Network (MU-SPIN), will be solicited for applications. Selected students will each be assigned to a science project group and by the end of each summer, they will gain a deep understanding of the specific area of solar and space physics within which they have been working, as well as a broad background in all of the areas of the field represented by the consortium (including plasma physics, helioseismology, solar magnetic field and magnetic reconnection, modeling CMEs and the solar wind, magnetospheric structure, modeling and assessing impact of geomagnetic storms). Through the summer school, brownbag research seminars and social events, students will increase their proficiency in student-to-student communication in both a scientific and community context, as well as establish a close working relationship with their faculty mentor, post-docs and graduate students. If successful, this REU program and its associated summer school has the potential to generate a significant number of undergraduates with increased interest and backgrounds in solar and space physics that will then feed into graduate programs across the country.

1b. *Why Solar and Space Physics and Why Boulder?*

The National Research Council, in its decadal study of solar and space physics, raised concerns regarding the number of solar and space physicists engaged in the field. Declining enrollments in undergraduate programs in both physics and Earth sciences has led to limited availability of courses in solar and space physics, threatening the pipeline of future researchers in the field (National Research Council, 2003). As part of their recommendation, the panel suggested that undergraduates should be encouraged to pursue research in solar and space physics through the programs such as NSF's REU program. The University of Colorado has experienced a similar decline in the number of students pursuing solar and space physics over the last decades. In part, this was the result of an erosion of the number of tenure-track solar and space physics faculty at the university, which, ironically, coincided with an increase in the number of solar and space physics researchers both at the university and throughout the Boulder area. The tide has begun to turn with the hire of a new solar physicist, Dr. Mark Rast, as part of the NSF program for bridging positions in solar and space physics.

In late 2004, solar and space physicists from a wide range of research institutions in Boulder began to meet regularly as part of the Boulder Solar Alliance (BSA) with the goal of increasing cooperation and coordination of our activities. The BSA includes the directors and scientists from CU's Laboratory for Atmospheric and Space Physics, CU's JILA, NOAA's Space Environment Center, NCAR's High Altitude Observatory, the Southwest Research Institute, and the Colorado Research Associates (a division of NWRA). One of the primary topics of conversation has been the need to increase support for both graduate and undergraduate training in solar and space physics in the area, utilizing the large pool of scientists from all of the institutions to increase educational opportunities. This spring, it was decided that, as a group, we would work to develop a comprehensive undergraduate training program that had both a summer school and a research component to it. We see this both as an opportunity to provide support for the training pipeline while at the same time fulfilling the desires of some of our scientists, particularly those at non-academic institutions, to interact with undergraduates. Our goal is to excite and engage students in topics across the solar and space physics spectrum, while at the same time developing a deep understanding of how scientists in a given subdiscipline approach their research.

1c. *The Space and Solar Physics Community at CU/Boulder and Beyond*

Boulder enjoys one of the largest concentrations of solar and space physicists anywhere in the world. From helioseismology to impacts of space weather on satellites, the scientists span the breadth and depth of the Sun-Earth connection. Boulder is unique in its range of solar and space physics programs with everything from instrumentation capabilities to significant ties to observational communities to modeling and forecasting.

<u>The Laboratory for Atmospheric and Space Physics:</u> We propose that the REU Site be housed in CU's Laboratory for Atmospheric and Space Physics (LASP). LASP, as a research entity, covers the fields of solar and space physics most broadly on campus, housing the largest concentration of tenure-track and research scientists in the discipline at the University. LASP supports research in planetary science, atmospheric research,

solar influences, and space plasma physics. The Laboratory has over 200 professional staff and over 125 student employees. Of the professional staff, about 50 are Ph.D. scientists and of those, about a dozen are tenured or tenure-track faculty members. Five of the tenure-track faculty are in the space physics disciplines; five are rostered in the Astrophysical and Planetary Sciences (APS) Department and one is in the Aerospace Sciences and Engineering (ASEN) Department. The solar influence group at LASP has 11 research scientist involved in seven active NASA/NOAA satellite programs, measuring the solar irradiance. The space physics group has 9 research scientists involved in a variety of instrumentation and modeling programs, including NSF's Center for Integrated Space Weather Modeling (CISM).

Departments with Solar and Space Physics Programs: The University of Colorado has solar and space physics graduate programs as part of four departments on campus. Each has specific areas of specialty and interest, and cross-department interaction (e.g. cross-listing graduate courses) occurs with some frequency.

Astrophysical and Planetary Sciences: The Department houses both astrophysicists and planetary scientists, making it a unique place where observers, theorists, and instrumentationalists from these two disciplines meet on a common ground. Faculty include: Dr. Daniel Baker (Space instrument design and calibration, space physics data analysis, and magnetospheric modeling), Dr. Fran Bagenal (Magnetic fields and plasma environments of solar system objects mainly Jupiter, the Sun, other planets, comets and asteroids), Dr. Robert Ergun (Space and astrophysical plasma studies), Dr. Mark Rast (heliophysics with an emphasis on solar granulation) and Dr. Juri Toomre (Astrophysical fluid dynamics).

Physics: The Department has specialties in geophysics, condensed matter and is home to the Center for Integrated Plasma Studies (CIPS). Faculty includes Dr. Mihaly Horanyi (Dusty space and laboratory plasmas), as well as Dr. John Cary, Dr. Martin Goldman, Dr. Scott Parker, and Dr. Scott Robertson.

Aerospace Engineering Sciences: A leader in the training of future aerospace workers, the Department has launched a new Ph.D. option in "Space Environment". Faculty includes Dr. Xinlin Li (Dynamics of Earth's space environment, particularly in the magnetosphere), Dr. Jeffrey Forbes (Theoretical dynamics and electrodynamics of Earth's mesosphere and lower thermosphere and ionosphere), Dr. Scot Palo (Upper atmosphere dynamics, TIMED mission), Dr. Susan Avery (Radio sounding of the ionosphere) and Dr. Jeffrey Thayer (Upper atmosphere dynamics).

Program in Atmospheric and Oceanographic Sciences: An interdisciplinary program that provides an educational and research environment to examine the dynamical, physical, and chemical processes that occur in the atmosphere and the ocean with an expertise in atmospheric chemistry and aerosols. Members include Dr. Brian Toon (Atmospheric chemistry and planetary atmospheres), Dr. Peter Pilewskie (Atmospheric radiation and solar flux), Dr. Cora Randall (Satellite remote sensing of the Earth's atmosphere).

Solar and Space Physics beyond CU: The broader Boulder community offers a tremendous environment for solar and space physics education. Boulder is the home of NSF's National Center for Atmospheric Research (NCAR). NCAR has over 1000 employees working on various aspects of atmospheric and space science. One of NCAR's divisions, the High Altitude Observatory (HAO), is specifically devoted to solar-terrestrial research. The sun is studied from its interior out into its extended atmosphere, with an emphasis on the physical processes that produce variable output of solar radiation and particulate matter, on time scales from seconds to millennia. The influence of such solar variation on the energetics, dynamics, chemistry and electrodynamics of the Earth's middle and upper atmosphere and the near-space environment is likewise an area of focused study, with the goal of understanding and how those influences might evolve and contribute to the Earth's climate variability.

In addition to NCAR, Boulder is also the home of the NOAA Space Environment Center (SEC). The Space Environment Center is the nation's civilian space weather forecasting center. It continually monitors and forecasts Earth's space environment; provides accurate, reliable, and useful solar-terrestrial information; conducts and leads research and development programs to understand the environment and to improve services; advises policy makers and planners; plays a leadership role in the space weather community; and fosters a space weather services industry. The SEC has 45 professional staff that supports its forecasting and science mission.

There are many other space-related research and development entities in Boulder. For example, there is a large branch of the Southwest Research Institute (SwRI) in Boulder, the SwRI Department of Space Studies. This group, with over 35 PhD researchers, focuses on planetary and solar physics. The Colorado Research Associates (CoRA), a division of Northwest Research Associates, focuses on modeling the large-scale structures in the solar corona, as well as studying gravity wave forcing, energetics and variability in the mesosphere and lower thermosphere as part of the TIMED mission.

The point of this listing of laboratories and companies is that undergraduates participating in this REU program will enter a very special – perhaps one could even say, unique – research and teaching environment. There are almost limitless opportunities for undergraduates to explore solar and space physics research and to collaborate with other scientists inside and outside the confines of the University. The summer school and follow-on community activities will ensure that students gain the widest possible set of experiences with which to move forward.

1d. ***Targeted Student Populations***

In assembling the REU program in solar and space physics, we are paying particular attention to the diversity of the students participating. The scientists of the Boulder Solar Alliance consortium have identified two target student populations for specific recruitment efforts. First, we hope to use the NASA Minority University-SPace Interdisciplinary Network (MU-SPIN) to help us attract underserved/underrepresented students from primarily minority-serving institutions across the country. To help train the next generation of NASA's minority scientists and engineers, NASA created MU-SPIN. MU-SPIN was started in 1990 by the Office of Equal Opportunity Programs and has remained a highly effective tool as it has continually grown and evolved over the past decade. The program serves America's Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs) and Tribal Colleges. LASP has been working with MU-SPIN over the last 3 years in a number of education and outreach efforts. James Harrington, director of MU-SPIN, is looking forward to using his network to identify and recruit qualified minority students for the Colorado REU program.

In addition, applicants will be sought from small undergraduate programs across the country that do not have consistent access to research experiences, particularly in the sciences. Using a combination of mailings and direct contact, our goal is to attract high quality undergraduate applicants from across the country.

Lastly, as we establish the make up of students in the REU program, we will be looking for a balance in the group's background and experiences. We are hoping to attract a mix of students with science, engineering and computational background, feeling that this will allow all students to gain maximum exposure to a variety of paradigms that could be used in solar and space physics.

1e. *Organizational Structure*

The PI, Dr. Dan Baker, is responsible for the overall implementation of the REU program with logistical support provided by Dr. Emily CoBabe-Ammann, the head of education and public outreach for LASP. Dr. CoBabe-Ammann's office is responsible for implementing and supporting many of the undergraduate programs at LASP, including providing logistical support, program development, and student advising. However, the Boulder Solar Alliance scientists share a collective role in the program's success, meeting regularly to talk about philosophies and strategies for undergraduate mentoring and working in concert to develop the summer school and research seminars to heighten the participants' experience.

1f. *Timetable*

Recruiting for the REU program will begin informally this fall through contact with our solar and space physics colleagues at meetings. In the early spring, we will begin formally advertising the program, including mailing, working with MU-SPIN, and developing our website, where project opportunities and scientist profiles will be posted. Even though we don't anticipate notification until late in the spring and will mark all materials clearly as "Pending Funding", we feel it is important to get a start on recruiting early. Throughout the spring 2007, we will work with CISM and consortium scientists to develop the summer school curriculum. Even if the summer school does not go forward next summer as part of the REU, we will look for ways to begin the program in the summer of 2008, feeling that it is a critical educational opportunity for the solar and space physics community.

By mid-spring, we will ask our consortium science team to propose their summer projects to the BSA. The proposals will be competitively vetted by the BSA and refined to ensure that the scope of work is commensurate with the expectations of an undergraduate summer research program. Successful science teams will attend a half-day training on working with and mentoring undergraduates. In addition, the REU summer school and research program website will go up (see below). During spring, we will begin to accept applications for the summer program and for the summer school. Applications will be due in mid-March with notification of acceptance in mid-April – again with a clear understanding that it is dependent on funding. Logistics of group housing, participant travel and stipends, pre-program evaluation, etc., will be arranged through the office of Dr. CoBabe-Ammann. The REU program will run from mid-June to mid-late August, starting with the 2-week summer school.

1g. *Institutional Commitment*

In this proposal, the LASP and its partners request support for 8 undergraduate participants each summer from NSF, along with nominal administrative and evaluation support. In addition, the consortium has committed its own funds to support four additional undergraduate participants and partial administrative costs for the program. The total cost of matching funds is approximately $150,000, or the equivalent of roughly 40% of the NSF request (not including the value of the IDC waiver). The consortium scientists are donating their time for the summer experiences, as well as lab supplies and expendables for their undergraduate researchers. The consortium scientists have agreed to participate in the summer school and the research seminars.

2. Nature of Student Activities

2a. *Philosophy of Our Program*

The philosophy of the faculty with respect to this REU Site Program is summarized as follows:

- It must be well-structured to ensure that the students accomplish a meaningful piece of research;
- Projects must involve research that excites student interest and creativity; not routine busy work;
- Students must feel that their work is an important part of the overall effort of a research team; and
- Students must obtain new skills and a clear understanding of how research is done.

We feel that the best means of achieving undergraduate excellence in science as part of any program is to engage the students in the nuts-and-bolts of carefully crafting a hypothesis, testing the hypothesis by the assembly of data and reporting the results of their tests. The key to success with undergraduates in this endeavor is to have a well-planned course of research for them, while at the same time recognizing the need for an opportunity for discovering something new and exciting [and of developing their own research program to the extent that this is possible]. Further, solar and space physics gives students the opportunity to become well-versed in the science of the discipline within which they work day-to-day, but also to understand the differing paradigms involved in other aspects of field.

2b. *Selecting Student Projects and Training Science Teams: A Commitment to Quality Education*

With so many of the scientists involved with the Boulder Solar Alliance in non-academic institutions, working with science teams to develop suitable undergraduate research programs is an important task. Throughout the academic year, leading up to the summer REU program, Dr. Emily CoBabe-Ammann will work with BSA scientists to craft research opportunities to meet the needs of summer researchers. A current survey of BSA scientists suggests that there are more research ideas floating among the consortium than there will be students to participate. Science teams interested in involving undergraduates in their programs will be asked to write up a project proposal in the spring. Proposals will be reviewed by the BSA scientists and evaluated on the basis on scientific promise and feasibility within the REU context. The top tier of proposals will move forward to be matched with incoming student interest. Proposals not reaching the top tier will be returned with comment, and Emily will work with scientists on those proposals for resubmission the following year.

Successful undergraduate research science teams will attend a half-day training on mentoring undergraduates involved in research programs, run by Emily CoBabe-

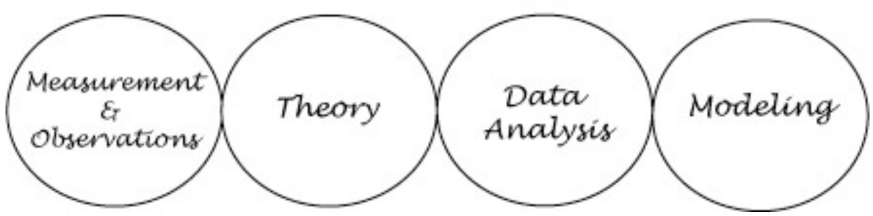
Ammann and scientists at CU-Boulder with extensive undergraduate researcher experience. Scientists across the BSA have requested this training, as many of them do not come into contact with undergraduate on a regular basis. Goals of the training include:

- Role of a mentor in undergraduate research programs.
- Setting expectations for students, based on the research project and their abilities.
- How to work with students to develop a work plan that outlines both short and long-term goals and a timeframe for reaching them.
- How to help students break up large tasks into smaller ones so that they aren't overwhelmed. How to help students understand a linear flow or a series of stages within their larger research process.
- Help mentors develop a system for keeping track of their student interactions.
- How to encourage students to take an active role in the critical feedback process.
- How to temper criticism with praise.

2c. *The Solar and Space Physics Summer School for Undergraduates: Partnering with CISM*

The REU site program would begin with a two-week undergraduate summer school in solar and space physics, developed in partnership with the Center for Integrated Space Weather Modeling (CISM) and modeled on CISM's successful graduate summer school. The summer school will take a 'whole system' approach to studying the Sun and its interactions, utilizing the talents of scientists from across the consortium to give the students an 'end-to-end' research experience in solar and space physics observations, data analysis and modeling. The summer school would be required for all REU site undergraduates, but would be open to any qualified undergraduate interested in participating, including the undergraduates involved in research through CISM and cadets from the Air Force Academy in Colorado Springs, for example.

The course would be modular, with specific activities focused on several research paradigms at the core of solar and space physics (observations, data analysis, modeling and theory). During each module, students will approach the subject (such as helioseismology) using several of the paradigms in a series of hands-on activities. Topics for the modules are designed carefully to ensure that, in the limited time available, students can develop an understanding of the fundamental aspects of the field being explored.



The modules will be team-taught by a core group of scientists from the Boulder Solar Alliance consortium, and each unit will have data problems and research experiences developed from the latest scientific work being produced by the teaching team.   In addition, new solar and space physics faculty, hired through the NSF Faculty Bridging program, would be invited to participate, giving them a chance to exchange teaching notes and experiences, as well as forge a strong working group relationship.

The Center for Integrated Space Weather Modeling (CISM) has developed and implemented a successful 2-week summer school, directed at students early in their graduate school careers, for the last 5 years. The CISM summer school also serves as an introduction to solar and space physics, with an emphasis on the phenomenological and applied aspects of space weather. Several of the lab-based activities, including model-based activities that explore solar wind structure and predict the arrival of CME's at Earth, would be ideal for incorporation into the undergraduate program. CISM Educational Director, Nicholas Gross, will work with the Colorado team to modify some of the CISM material, particularly its labs, for use in the Colorado summer school. The Colorado summer school, though having a broader range of topics and paradigms it hopes to explore, will benefit from Gross' experience running the CISM program, particularly in the areas of content development, workloads, and logistics. This opportunity leverages investments by NSF through CISM in education and all products from the Colorado summer school would be available to CISM for their use in developing their undergraduate program.

As currently envisioned, topics for this course could include: 1) Plasma Physics, 2) Anatomy of the Sun (helioseismology, solar magnetic field and magnetic reconnection, solar activity), 3) Solar Activity (Flares, CMEs, solar energetic particles), 4) Solar Wind and its interactions, 5) Magnetospheric Structure, 6) Ionospheres and Atmospheres (impact of solar radiation, geomagnetic storms) 7) Space Weather (impact, prediction and applications). We anticipate that the topics, or at least the research problems presented in the course, may change, depending on the teaching teams, their areas of expertise, and the current hot topics in the field.

2d. ***The Undergraduate Research Program***

Each project will involve at least two scientists from across the consortium. Each student will:

Be assigned one of their first three choices of research projects;
Meet several times per week with their science teams;
Participate in the weekly research group meetings of their science mentors;
Participate in a weekly brownbag research seminar;
Make a presentation on their research at the weekly brownbag seminar; and
Write a final report on their research [that might be incorporated into a manuscript for publication, if appropriate].

The goal of this program is to provide as varied an educational experience as possible, from in-depth and responsible research to scientific communication across a wide range of fields to exposure to a variety of scientific venues (from the field to the lab). More than simply learning about one area of work in isolation, we are designing a program that, through its interdisciplinary nature, challenges students to focus on how to do research, evaluate peer-reviewed literature, develops critical thinking, apply ethics in research, solve problems, and searching for solutions.

2e. ***Examples of Research Programs in Solar and Space Physics***

The scientists of the Boulder Solar Alliance consortium offer a wide variety of subjects to be explored by undergraduate researchers. The breadth of their work translates into a breadth of experience for participants, who will work intensely on one program but be exposed to the entire spectrum. Examples are described briefly below.

Exploring the Sun's magnetic field and its impact on solar activity (Tom Metcalf, CoRA): Dr. T. Metcalf is participating the joint NASA/JAXA Solar-B program that will launch from Japan in September of 2006. This exciting space program will provide an unprecedented dataset for understanding the magnetic connections between the solar photosphere and corona and for understanding how the solar corona is energized. Under the supervision of their mentors, students would have the opportunity to access this unique dataset and learn about the solar magnetic field at very high spatial resolution.

Magnetostatic solutions of coronal helmets with prominence sheets (Yuhong Fan and BC Low, HAO/NCAR): Coronal helmet streamers are large-scale structures in the solar corona seen above the solar limb during a solar eclipse or with a coronagraph. They correspond to regions of closed magnetic field surrounded by the open field stretched out by the solar wind. Prominences are often situated beneath helmet streamers. The magnetic field of a coronal helmet can spontaneously open up with the prominence lifting off, resulting in a coronal mass ejection (CME). This project constructs idealized 2D axisymmetric global magnetostatic solutions that reflect the basic features of the underlying magnetic field of a corona helmet streamer. In carrying out this project, the student learns to solve numerically the linear elliptic equation for a potential magnetic field with mixed boundary conditions (which create the necessary current sheets). From the resulting solutions, the student can investigate the role prominence mass plays in anchoring detached magnetic flux within the coronal helmet and thus building up magnetic energy to exceed that of the open field energy limit.

The eruption of a coronal filament cavity (Sarah Gibson and Giuliana de Toma, NCAR-HAO): Coronal mass ejections (CMEs) are huge eruptions of magnetized plasma from the solar atmosphere. These solar storms can cause significant damage to satellites, communications, and electrical systems at the Earth, so it is essential to understand their origins at the Sun. It is generally accepted that the driving force behind CMEs comes from magnetic energy stored in twisted, or sheared magnetic fields. Such twisted magnetic fields can manifest themselves in a particular coronal structure known as a filament, which is relatively cool, dense material often observed suspended in a surrounding cavity. The entire filament cavity system can eventually erupt as a CME. The goal of this summer project will be to study an example of such a filament cavity eruption using a variety of solar observations, in order to gain insight into what makes it erupt. The student will learn how different aspects of coronal plasma can be observed in different wavelengths of light, depending on its local temperature, density, magnetic field, and velocity properties.

The source of solar variability (Mark Rast, CU-LASP): The Sun's radiative output is variable at the level of 0.1%. The source of this variability is thought to lie in the changing number density of magnetic structures in its surface layers. The Precision Solar Photometric Telescope (PSPT) was built to resolve such structures on the Sun and measure their relative radiative output with 0.1% precision. That telescope has been collecting data for eight years, and that data is a shared HAO/LASP archive. The undergraduate project proposed would investigate changes in the magnetic structures observed on the Sun as a function of the solar cycle. Students would learn to interface with the PSPT data (written in the commonly used astrophysical fits format), apply IDL analysis programs to extract magnetic structure types from the images, and catalog the number of those structures observed each day over the declining phase of the last solar cycle. An ambitious student could also be involved in modeling the radiative output of the Sun using that catalog.

<u>Exploring long-term trends in Solar Variability (Tom Woods, Gregg Kopp, Jerry Harder, CU-LASP):</u> This summer project, designed for a geoscience-oriented undergraduate student, focuses on estimating the long-term trend of the solar irradiance for the climate community. The cooler climate period of the Maunder Minimum (roughly 1645 to 1715 A.D.) is a time when few sunspots were recorded, and it has become a focal point for study of solar influences on climate. New, improved estimates of the solar irradiance during the Maunder Minimum, brought about by a better understanding of how the solar irradiance can change and by improved accuracy and precision of the solar variability, means that we can evaluate more effectively the impact of solar forcing on Earth’s climate. Students would work on analysis of the variability of the solar spectral irradiance from current measurements and then the application of these results to students of long-term variability.

<u>Calibrating SDO EVE, Glory TIM, and EVE's annual calibration rocket at LASP: Instrumentation to Explore the Sun (Tom Woods, Frank Eparvier, Erik Richards, Gregg Kopp, CU-LASP):</u> During the summer of 2007 through 2009, we anticipate that LASP will be performing a series of calibration activities on several solar instruments, including SDO EVE, Glory TIM, and EVE's annual calibration rocket. Undergraduates with an interest in scientific instruments will perform calibrations of these instruments, using advanced radiometric standards in high-vacuum systems. These calibration students will operate the calibration equipment and vacuum tanks in the LASP calibration laboratories to obtain the instrument data, analyze these calibration data, and present the calibration results in both written and oral forms to the instrument team members.

<u>Exploring Space Weather on Jupiter (Fran Bagenal, CU-LASP):</u> Jupiter’s magnetic field and its interaction with Io offers an opportunity for students to explore the impact of space weather on other planets. Undergraduates can work on a variety of projects associated with the magnetic fields of planets and the energetic charged particles that are trapped therein. Projects involve data analysis, theoretical modeling and planning of future scientific measurements by space missions to planets - particularly the Juno mission to Jupiter, the New Horizons mission to Pluto (plus its Jupiter flyby in spring 2007) and future Mars missions.

<u>Global simulations of magnetospheric substorms (S. Elkington, D. Baker, CU-LASP):</u> Large-scale simulations of the magnetosphere and its energetic particle environment provide an opportunity for students to learn not only about the basic physics and global characterization of processes in near-Earth space, but also of the larger interactions between the solar wind and Earth's intrinsic magnetic field. For this project, students will use available lists of identified substorm onsets based on spacecraft and ground magnetometer observations to gather and analyze the solar wind data required as input for the magnetospheric simulations. Under the supervision of their mentors, they will run the simulations on the large-scale computer architectures required by such models and will examine the simulation results for the magnetospheric changes characteristic of a global substorm onset.

<u>Validating and Extending Operational Solar Energetic Particle Models (Doug Biesecker, Chris Balch, and William Murtagh, SEC):</u> Solar energetic protons (SEPs) expelled from the Sun in violent explosions are a major concern for astronauts, airlines, satellite operators, and satellite launch providers. Astronauts will change extra-vehicular activity plans, airlines will divert planes in flight, and satellite launches will be scrubbed during such events. Until now, all customers have been forced to rely on the same forecast, even though different customers have different needs. For example, the >100MeV protons are critical for astronauts inside the space station, while >30MeV protons are important for airlines. The operational SEP model used by SEC has been validated only for the >10MeV peak flux, >10MeV time of peak, the probability the >10MeV event flux will exceed a predefined threshold, and for the >100MeV peak flux. One project would be to test the additional predictions as well as extend the model to additional energies, including peak flux predictions for >30MeV and >50MeV particles. In addition, the probability an event will exceed a predefined threshold is only calculated for one threshold level.

Implementing a Radiation Environment Tool (Rodney Viereck, Janet Green, and Terry Onsager, SEC): The Earth's magnetosphere is filled with extremely high energy electrons and protons (moving at velocities approaching the speed of light) trapped by electromagnetic forces. These high-energy particles can penetrate through satellite exteriors, damaging sensitive electronics, and even disabling satellites. One objective of the Space Environment Center (SEC) is to monitor the numbers of these high-energy particles and warn satellite operators when the particle numbers become high enough to pose a threat. The environment is monitored by operational satellites carrying detectors that continually measure the numbers of energetic particles. Software has been developed that will translate these satellite measurements in real time into threat levels that can be easily interpreted by satellite operators. The goal of this summer project is to have students work with SEC professionals to make the software operational, test and modify the software to meet SEC needs, and to develop a web-based interface that allows threat levels to be updated in real time. The goal is to develop the software and the interface as an operational product at the SEC.

Cause and Effect of Space Weather on the Cluster spacecraft (D. Baker, S. Elkington, X. Li): The study of space weather, those changing aspects of the Sun-Earth environment that directly affect human technology in space, has become increasingly important as global society has become more dependent on space-based platforms for communications, navigation, weather prediction, and a variety of other economic and geopolitical purposes. This project studies the effect of space weather on a specific scientific platform, the Cluster spacecraft, and provides an opportunity for students to become directly involved in the practical implications of space weather on human technologies. Based on a list of operational anomalies noted over the lifetime of Cluster, students will examine the nature of the spacecraft disruptions, learn about the possible causes in terms of space environmental effects, and attempt to correlate the anomalies with actual space weather conditions. This project would provide a framework for instructing the student in the effect of the space environment, the use of indices in estimating the dynamic state of the sun-Earth system, and sources of data relevant to characterizing the operational space environment.

2f. *Weekly Brownbag Research Seminars*

In addition to the weekly workshops where students are building their backgrounds in solar and space physics, the brownbag seminars provide an opportunity for students to hear about the latest cutting-edge solar and space physics research from faculty and post-docs. Attended by all of the students and scientists, this forum provides an opportunity to stimulate communication within the group. As the summer progresses and students begin generating results of their own, they will be required to give a half hour presentation in the brownbag where the outline their work, its importance to the field of solar and space physics, and the results.

3. The Research Environment

3a. *The Members of the Boulder Solar Alliance: Facilities and Support*

CU-LASP: The University of Colorado's Laboratory for Atmospheric and Space Physics (LASP) is a full-cycle space science institute with capabilities in science, engineering and mission operations. The Laboratory, with over 100,000 sp. ft. of laboratory, computing and office space, will be able to provide workspace and lab space (as needed) for the REU students. In addition, conference rooms, auditoriums, and computer facilities are available for the summer school.

NCAR-HAO: Conference rooms, ranging from small to huge for workshop and other group or subgroup activities. Computer access, including wireless, will be available for participants while at HAO. Work environment (cubicle, computer, etc.) for undergraduates working at HAO. HAO also acts at the data center from several telescopes, including the Precision Solar Photometric Telescope (PSPT).

NOAA-SEC: NOAA's Space Environment Center (SEC) is the national civilian center for disturbances in the space environment that can affect people and equipment. The Center has three functional areas: Forecast and Analysis Branch, Science and Technology Infusion Branch, and Technology Support Group. Resources of these areas can be used in support of the REU program and its summer school.

CoRA (NWRA): CoRA has office space, computer facilities, and conference rooms to be used in support of the REU program.

3b. *Current and Past Involvement of Undergraduates*

While not all of our consortium partners have had opportunities to work with undergraduates (and hence are particularly looking forward to the REU program), LASP and HAO both have a track record of undergraduate research. LASP has been involving students in its research programs since its inception. Currently, we have 125 undergraduate and graduate students (about evenly split) working in every aspect of the lab. In the last several years, our undergraduate programs have expanded. Opportunities include 40 students involved in designing, building and testing the Student Dust Counter, now on its way to Pluto as part of the New Horizon Mission, 35 students support our mission operations program, and a five involved in building instrumentation and integrating it on our sounding rocket launch, slated for October 2006. The REU program is an opportunity for us to develop a model for formalizing our undergraduate programs.

At NCAR's High Altitude Observatory, opportunities to interact with undergraduates come in the form of formal programs. SOARS (Significant Opportunities in Atmospheric Research and Science) is an NCAR program that works to increase participation of minority students in the geosciences. Several of the HAO scientists here (including Gibson and Fan) have been involved in the program over the last 5 years. In addition, HAO also hosted the first AAS/SPD summer school on helioseismology July 25 – 29, 2005. (http://www.hao.ucar.edu/summerschool/index.html)

Many of our consortium scientists, though certainly not all, have been involved in the education of undergraduate researchers. In many cases, those without extensive experience can look to the lack of opportunity, something that can be remedied by this program. A summary of their involvement over the last several years is found in the following table:

Faculty	Area	#Students	#Publications	Follow-up
Dan Baker, CU-LASP	Magnetospheric interactions	6 (in 5 years)	5	2 to Grad. School; 3 entered Industry
Fran Bagenal, CU-LASP	Planetary magnetospheres	9 (in 5 years)	6	3 to grad school, 2 became teachers
Tom Woods*, CU-LASP	Solar irradiance	5 (in 5 years)	0	2 to Grad School; 1 hired by LASP; 2 still undergraduates
Yuhong Fan*, NCAR-HAO	Solar interior. MHD	1 (in 7 years)	1	Went to Grad school
Sarah Gibson*, NCAR-HAO	Solar corona	1 (in 1 year)	2	Still enrolled
Doug Biesecker*, NOAA-SEC	Comets, space weather	2 (in 5 years)	1	Both in Grad school

*Research scientist with no traditional access to undergraduate students
+ New to faculty, Spring 2006; Research scientists previously.

3c. *Diversity among the scientists and students in Solar and Space Physics in Boulder*

The diversity in the Boulder solar and space physics community, in terms of scientists and students, reflects national trends – overwhelmingly male and white. The BSA scientists are committed to working on balancing that picture. A summary of the BSA demographics is provided here:

University of Colorado: Solar and Space physics scientists at CU are comprised of 20% female and 12% non-white scientists. Student populations have a higher percentage of women (25%) and minorities (20%).

The NOAA Space Environment Center's scientists' demographic is 29% female and 13% minority.

The High Altitude Observatory at NCAR is 31% females and 14% minority.

CoRA is 20% female and 5% minority.

4. Student Recruitment and Selection

4a. *Advertising*

We will design a brochure that will be used in conjunction with the direct recruiting efforts discussed below. The requested information in the application includes the student's transcript, two letters of recommendation, a resume, and a brief narrative that discusses the student's interest in this program, research interests, and career goals.

We will also develop a website for the REU program that will have applications for download for both the summer school and the research program, the syllabus and materials for the summer school, profiles of scientist teams and research projects, background reading suggestions, accessibility to REU staff to answer questions.

4b. *Recruiting Efforts*

We plan on using several networks already in place to promote and recruit for our REU program and summer school. In addition to utilizing the MU-SPIN network, mentioned above, to attract students from Historically Black Colleges and Universities (HBCUs), Hispanic Serving Institutions (HSIs) and Tribal Colleges, we will also advertise through national minority professional organizations, such as American Indian Science and Engineering Society, the Hispanic Association of Colleges and Universities, and the Society for the Advancement of Chicanos and Native Americans in Science. We will use the CISM network of institutions, places that already have strong interests in solar and space physics, as well as AGU's education office and its Space Physics and Aeronomy Education working group (of which Emily CoBabe-Ammann is Secretary). We will advertise through established online channels, such as CEDAR. Lastly, brochures will be sent out to the physics, astronomy, chemistry and engineering departments of 100 of the top undergraduate colleges in the country. BSA members will be encouraged to contact colleagues at undergraduate institutions to facilitate the recruiting efforts.

4c. *Financial Provisions and Local Arrangements for Students*

Students participating in the REU summer research program will receive a stipend of $400 per week for the summer program (~$3200 per summer). In addition, they will be provided with an allowance for room and board in CU's Housing (double occupancy, 5 meals per week) in a set of rooms that are blocked together. Students will receive up to $400 towards their travel. The students will be assigned working space at their science teams' institution and will be provided with access to the CU computing system, libraries, and Recreation Center. Funds for research materials and supplies are provided by the faculty mentors.

4d. *Selection Process*

We will strive for significant participation by women, minorities, and physically disadvantaged students. In all cases the student's research interests will be matched to available projects. The student's GPA, written statement of interest in this program, activities, and letters of recommendation also will be important in the selection process. Scientists and support staff will review REU applications, ranking students both in terms their application and in terms of fit into specific programs.

5. Project Evaluation and Reporting

A series of formative and summative evaluation tools will be used to determine the progress and effectiveness of the REU program at during development and to ultimately determine the impact of the programs on participants. Our evaluation will employ a pre-summer and a post-summer anonymous survey to gauge the impact of the program, both in terms of participant growth and to determine areas where the program might be improved. Our hope is to develop tool that combines both qualitative and quantitative information on what the students learned and how their perspectives on solar and space physics have been broadened. In addition, participants will be polled for ideas for program improvements, new lines of inquiry, and suggestions for activities are a vital component of the program development.

Periodically throughout each summer, students will meet with program staff to see how things are going, identify any trouble spots, and make sure that the program is meeting the participants' needs. This will provide critical feedback for the staff and allow the program to be optimized for each student. Likewise, throughout the program, science teams will be asked to assess the progress of the undergraduate, in hopes of identifying problems that might be addressed "mid-flow".

Students will continue to be followed up annually by program staff to identify career choices and destinations. Follow-up will include career surveys developed by LASP to track its graduate students after they've completed their degree. We will modify this survey for the REU program. It is our hope to be able to track students for at least 5 years. Depending on their career track, this will allow us to gauge their pursuit of advanced degrees and/entry into a profession.

6. Results from Prior NSF Support

The University of Colorado currently has 4 REU sites supported through NSF: 1) REU Site in Cybersecurity (in the Dept. of Computer Sciences), 2) REU Site in Functional Materials (in the Dept. of Chemical Engineering), 3) REU Site in Behavior, Ecology and Evolution (in the Department of Environmental, Population and Organismic Biology), and 4) REU Site in Climate Modeling and Societal Impacts (in the Center for Integrated Research in Environmental Sciences). Several of these (Functional Materials & Behavior, Ecology & Evolution) have been running very successfully for many years.

Demographics for some of the current CU REU programs:

REU Site in Functional Materials (Chemical Engineering) 2002

Number of Applicants	**150**
Number of Participants	**14**
Number of Women	**5**
Number of Minorities	**3**
Evaluation Methods	**3-page questionnaire**

REU Site in Behavior, Ecology and Evolution (in the Department of Environmental, Population and Organismic Biology) 2002

Number of Applicants	**150**
Number of Participants	**12**
Number of Women	**6**
Number of Minorities	**2**
Evaluation Methods	**Weekly assessment**

We have been in contact with each of these programs to glean the most from their lessons learned regarding the running of an REU site on the CU campus. Our hope is to continue the relationships we have established with the current REU programs, using their collective knowledge to help us make our path smoother. From logistics to broad programmatic themes, these groups have tackled many of the major obstacles we are likely to face, in one form or another, and they have kindly offered their assistance as we begin and move through our program development.