1. Science Investigation

- How and why does the Sun vary?
- How do the planets and Earth respond?
- What are the impacts for humanity?

1.1 Executive Summary. For decades, the search for answers to these fundamental questions has preoccupied solar and space physicists and has driven the plans for all Sun Earth Connections (SEC) missions. Although significant inroads were made with single-spacecraft missions, a radical new approach is called for to advance our understanding of our nearest star and its wide-ranging effects on interplanetary space and, more importantly, on our home planet. The STEREO mission is designed to view the three-dimensional (3D), and temporally varying heliosphere, by means of an unprecedented combination of imaging and *in situ* experiments mounted on duplicate spacecraft flanking the Earth in its orbit. The advantages of stereoscopic vision are imprinted on our very DNA, yet we are only now becoming sufficiently adept to use the same principles to construct a truly global picture of the active Sun and its influences.

To accomplish these goals, we are proposing the Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI), named after one of the first physicists (A. Pietro Secchi, 1818-1878) to use the new medium of photography to record solar eclipses. SECCHI will pioneer new techniques of synchronous interplanetary spacecraft operation and stereographic image reconstruction to develop a comprehensive 3D description of the Sun and heliosphere to 1 AU.

SECCHI is a suite of remote sensing instruments that maximizes science by coordinating all phases of the investigation to develop a light weight, cost effective and low risk package. SECCHI consists of two white light coronagraphs, an EUV imager, a magnetograph, and a heliospheric imager. Numerical MHD models and 3D analysis tools are essential for interpreting the solar and heliospheric observations and for connecting the optical and *in situ* observations made by STEREO as they occur during the mission. SECCHI includes a coordinated, international effort to provide such models and tools in time for launch.

For the first time, a magnetograph and an EUV imager will observe the photospheric magnetic field, chromosphere, and innermost corona underlying the same portions of the corona and the heliosphere observed by the coronagraphs and heliographic imagers. SECCHI will follow 3D CMEs from birth at the Sun's surface, through the corona and interplanetary medium, to impact at Earth. We anticipate major breakthroughs in understanding the origin and consequences of CMEs, in determining their 3D structure, in identifying the magnetic configurations and evolutionary paths leading to CMEs, in determining the key factors controlling their trajectories, and in achieving the national goal of predicting space weather.

The international team assembled for this effort has impeccable credentials in designing, building, flying, and extracting maximum scientific benefits from space missions. Members of the SECCHI team have built primary instruments on SOHO (LASCO, EIT, MDI, CDS), *Yohkoh* (SXT, BCS), TRACE, Spartan 201, and are currently fabricating instruments for SXI, Solar-B, and SMEI.

SECCHI relies on extensions of proven technology to access larger views and new viewpoints, with improved spatial and temporal resolution overall. VMAG, the Vector Magnetograph And Guidescope, implements a basic Stokes polarimeter design in a lightweight package. It provides the pointing signal to control the spacecraft fine pointing and a magnetograph that is optimized to detect the large-scale magnetic field and magnetic helicity relevant to solar eruptions. EUVI, the Extreme UltraViolet Imager, provides full Sun coverage with twice the spatial resolution and dramatically improved cadence over EIT. The coronagraphs, COR1 and COR2, will observe the inner (1.1-4 $R_\odot$) and outer (2-15 $R_\odot$) corona with greater frequency and polarization precision than ever before. COR1 will be the first spaceborne instrument to explore the inner corona in white light and pB down to 1.1 $R_\odot$. COR2 will image the corona with five times the spatial resolution and three times the temporal resolution of LASCO/C3. The most novel instrument, the Heliospheric Imager (HI), extends the concept of traditional externally occulted coronagraphs to a new regime—the heliosphere from the Sun to the Earth (12-300 $R_\odot$). HI will obtain the first direct imaging observations of CMEs in interplanetary space.

By combining the optical instruments into a common suite, sharing structure, electronics, cameras, development, and management, we have lowered not only the total mass, volume, and instrument cost, but also NASA's costs for management and hardware interfaces to the optical experiments. Our foreign partners will provide significant contributions, and the integration costs for two SECCHI telescopes will be subsidized by the DoD's Space Test Program. As a result, about 40% of the budget will come from sources outside NASA, allowing us to devote more resources to data analysis, interpretation, and modeling.

A strong numerical modeling effort is as much an integral component of SECCHI as any one instrument. Given the complex spatial and temporal structure of the Sun and heliosphere, we must use modeling to extract from the data an accurate three-dimensional picture of the corona, CMEs, and the heliosphere. This multifaceted modeling effort will yield a steady state, 3D description of the magnetic field, electron density and velocity from the photosphere to 1 AU, as well as CME initiation models, and CME propagation models.

In addition to deciphering the imaging observations, our numerical models will enable direct comparisons between SECCHI observations and *in situ* observations at each spacecraft. For example, the description of the solar wind generated by SECCHI's numerical model can be used by other instrument teams to predict the arrival of energetic particles.

The importance of coordinating the observations, as well as their analyses, can hardly be overemphasized. We have never before had an opportunity to observe from two well-separated viewing points. The stereoscopic techniques and their results will be entirely new; we can expect to be learning while observing. Furthermore, the opportunity will not be a static one, as the viewing characteristics will change continuously with the growing separation angle between the two spacecraft. It is for this reason, as well as for the economies of scale, commonality, and management, that members of the SECCHI Consortium have teamed together to present a coordinated approach for all the remote sensing instruments on STEREO. As a further step, toward integrating our observations with the *in situ* investigation teams, we have exchanged Co-Is and coordinated the development of SECCHI instrumentation and analysis programs with PIETRO (L. Fisk, PI) and SWAVES (J.L. Bougeret, PI); note, however, that our programs can easily be made compatible with those of any instruments that may be selected for the mission.

SECCHI has an open data policy. Calibrated data will be made public via the Internet within hours of its receipt. The SECCHI team will provide modern data visualization tools to display the information from one telescope, to overlay data from multiple instruments, and to visualize coincident data from both spacecraft. We propose to include the data from all STEREO experiments in the SECCHI data archive and in the distributed data products. This will enable any scientist convenient access to all STEREO data.

As was first suggested by the HESSI team, we are proposing to include within the SECCHI budget a Guest Investigator (GI) program, to be started about one year before launch, and administered by NASA as a standard peer-reviewed program for analysis and theory focused on STEREO science. This support is intended as a supplement to, not a substitute for, the ongoing SEC GI program.

STEREO's relevance to human life on Earth and the domestication of space provides a natural platform for enhancing the scientific and technological literacy of children and adults nationwide. Specifically, the spectacular imagery of the Sun and inner heliosphere to be obtained with SECCHI will provide unique opportunities for education and public outreach.