Living With A Star Program

Anderson, Brian J. / Applied Physics Laboratory
Global Magnetosphere/Ionosphere Specification: Low Earth Orbit Constellation Observations and Global Model Intercomparison

Previous research, missions and computer models have demonstrated that the magnetosphere-ionosphere system is astonishingly dynamic and sensitive to the solar wind. The measurements required to fully characterize the system are therefore extraordinarily difficult to obtain and global simulations will be essential to Living With a Star missions. It is therefore crucial to validate the global models. The low altitude polar region provides a 2-D window on the system and the Iridium system of communication satellites provides a unique opportunity to measure the global distribution of field aligned currents (FACs). Each of the Iridium satellites carried an engineering magnetometer and we have developed procedures to derive global distributions of FACs in both hemispheres from these data. Data available for analysis cover the time from February 18, 1999 through the time of writing. Because current is a fundamental MHD variable the FAC distributions derived from the Iridium system provide an unprecedented opportunity to validate the global models. We propose to test the global magnetospheric simulations by comparing the results of the Lyon-Fedder MHD code coupled with the Rice Convection Model against FAC distributions determined from Iridium system data. This work will address two questions: (1) Do the simulations give the right systems of currents? and (2) How accurately does the model represent the intensity, distribution and physical dependencies of the currents, including the expansion and contraction of the polar cap? These validations serve as a litmus test of the model and its representation of the solar wind-magnetosphere interaction. This work will quantify the confidence to be placed in the simulation results and produce a data base against which other models, either existing or future, may also be tested.

Braun, Douglas C. / NorthWest Research Associates, Inc.
Seismic Forecasting of Solar Activity

We propose to use standard techniques in phase-coherent seismic imaging to develop the capability for real-time monitoring of the deep solar interior and far side for space-weather forecasting applications. The advent of far-side solar imaging now opens the way for a quick, comprehensive and inexpensive synoptic monitor of large active regions anywhere on the solar surface. We will develop a flexible, portable software package for this utility. In the first year of the project we will implement a working demonstration of our ability topredict the appearance of large active regions from behind the solar limb up to a week in advance, using available SOHO-MDI observations. The ability to predict the emergence of solar activity from directly beneath the solar surface will also have immediate applications to space-weather forecasting. We will conduct a careful study to assess subsurface seismic Doppler and wave-speed perturbations as possible precursors to near-side active-region emergence. We will also extend our near-surface investigation to low spherical-harmonic degrees to probe for signatures of prospective surface activity deep in the convection zone. Finally, we will explore both forward and inverse holographicmodels in terms of subsurface sound-speed and Doppler variations that would give rise to the observed signatures.

Cattell, Cynthia A. / University of Minnesota
Determining the importance of energy transfer between magnetospheric regions via MHD waves using constellations of spacecraft

Living with a Star (LWS) will consist of many constellations of spacecraft designed to examine in detail parts of the sun-earth system, and, together, to examine the coupling between elements of the system. The data handling, analysis and visualization from so many satellites making coordinated measurements presents a major challenge. We propose to develop techniques to facilitate analysis of these complex data sets, so that the important questions for LWS goals can be answered. We will develop such techniques and visualization software with a focus on MHD waves, because a critical issue for developing a predictive capability for space weather is to determine via what mechanism and how rapidly energy is transferred from the solar wind and the inner magnetosphere and between different magnetospheric regions. Recent observations have provided clear evidence that waves may often be the dominant energy transfer mechanism. We propose to focus on the role of MHD waves, and particularly on the question of identification of wave modes, wave propagation and energy transfer via waves. In so doing, we will develop data assimilation, analysis and visualization techniques and software for missions consisting of constellations of satellites, and thus develop infrastructure for LWS. Our objectives lie in two areas: (1) development of new techniques and software for assimilation, analysis and visualization of data from multiple satellites making in-situ measurements; and (2) determination of the role of MHD waves in energy transport during storms and substorms. We will primarily use data from Cluster, launched near the beginning of the current solar maximum so that many geo-e ffective solar events can be expected to occur during the three year period of this proposal. We will make use of other spacecraft data sets and MHD simulations which are optimized to study wave propagation in the magnetotail to test our data analysis and visualization software.Our results will have a direct impact on OSS goals. The data assimilation, analysis and visualization techniques will provide vital infrastructure for many upcoming missions. Our research on wave transport of energy will provi

----

Chandler, Michael O. / NASA/Marshall Space Flight Center

The Analysis of the Predictive Capability of Solar Wind Parameters on Cleft Energization

Observations and simulations show that the largest portion of the cleft ion outflow, an important source of plasma to the magnetosphere, originates from a narrow (less than 2¡) latitudinal interval termed the cleft-heating wall. The cleft-heating wall lies just poleward of the closed field line region in the dayside sector. Furthermore, cleft ion heating and subsequent outflow have been shown to be sensitive to solar wind dynamics-particularly to the variability in solar wind dynamic pressure. This proposal addresses the direct coupling of solar wind energy to the cleft-heating wall region by quantifying ion energization as a function of solar wind conditions and thus determining its predictive capability. Observational analysis and an existing semi-kinetic model will be used to achieve this objective. Local wave power spectral densities and derived ionospheric parameters (i.e. temperatures, densities, and velocities) will be obtained from measurements from polar orbiting satellites such as FAST, Polar, and Interball-Aurora. These data will be combined with geophysical and solar wind parameters and used in a statistical study to determine relevant influences. The knowledge gained from analysis of this observational database will be broadened with the use of an existing semi-kinetic model that simulates ion heating through particle-wave interactions. The power spectral density (PSD) obtained from the observations will be used as an input to this model and will provide a strong connection to the solar wind influences. Our proposed objectives meet the following primary tasks of the Living with a Star (LWS) initiative; 1) Determine space weather predictive capability by providing an in-depth understanding and specification of how solar-dynamics drive ionospheric properties; 2) Enable improved space weather specification models by providing a database for model inputs to be used for forecasting.

Decker, Dwight / Air Force Research Laboratory
Modeling Ionospheric High Latitude F-region Plasma Structures

Observations have shown that the high latitude F region ionosphere contains a variety of large-scale plasma structures (polar cap patches, polar cap arcs, boundary blobs, subauroral blobs, auroral blobs, and auroral ionospheric cavities). Through the use of global F-region fluid models, researchers have successfully simulated the production and evolution of many of these structures. Some of the successes have involved demonstrating the efficacy of various mechanisms for producing typical patches or blobs. Other efforts have focused on simulating the climatology of these structures. However, there has been much less work on modeling these structures at a particular place and time. In this proposal, we plan to use a physics-based ionospheric model to specify on a given day where and when these structures will occur. We will focus on what is needed to accurately model the structures called patches and blobs (regions of enhanced F-region plasma density). We will address three issues: (1) What physical processes and numerical techniques need to be included in a realistic weather model? (2) How well do the inputs to the model need to be specified? (3) How does the model compare to observations?

While the first two issues can be explored with model sensitivity studies, it is only by comparing to observations that the relevance of the sensitivity analysis can be assessed. As a result, observations will be critical to the success of the effort. The importance of this work in large part comes from the observation that smaller scale plasma irregularities are often imbedded within the larger scale patches and blobs. These small-scale irregularities can cause scintillations in radio waves propagating through the ionosphere. Thus, understanding the production and evolution of large-scale plasma structures is a key component of being able to specify and forecast ionospheric impacts on radar and satellite operations in the high latitudes.

Decker, Robert B. / Applied Physics Laboratory Solar Proton Penetration at High Latitudes: Model Calculations of Cutoff Latitudes and Variations with Solar Wind Conditions

Solar energetic particles (SEPs) produced during active periods on the Sun can penetrate Earth's polar regions. SEP protons with energies greater than a few MeV have been observed by spacecraft in high-inclination, low-altitude orbits. SEP protons with energies of order 5-300 MeV that enter the polar ionosphere can produce the well-know PCA (polar cap absorption) events. Because of the high dose rates associated with a single large SEP event, the importance of predicting these events in the context of manned spaceflight cannot be overstated. In addition, an entire discipline is devoted to shielding sensitive spacecraft instruments from these particles. Typically, spacecraft mass constraints drive critical payload decisions because of shielding, especially in high radiation environments. It is noteworthy that even minor changes in orbital design can reduce hazardous doses/shielding requirements dramatically. Surprisingly, little is known about how these solar energetic particles enter Earth's magnetosphere and this has limited our predictive models of these important intensities. In this proposal, we plan to use state-of-the-art modeling and a current magnetic field model to determine cutoff latitudes of penetrating protons for a number of solar wind conditions. We will also use modeling and published data to determine intensity levels at high latitudes and low altitudes. These calculations will aid future mission design and shielding requirements.

DeForest, Craig / Southwest Research Institute
Novel Magnetic Models: Development and Application to CME prediction

We propose to develop detailed physical models of erupting active regions and filaments from the rich existing SOHO datasets, laying a foundation for practical, predictive modeling of coronal mass ejections (CMEs). Our approach combines archival SOHO data with a promising new technique, field line modeling. By applying a field line model to observed active regions and prominences, we will characterize pre-eruptive MHD

equilibria. By following the evolution of the system with a quasi-static model, we will determine the reasons for loss of equilibrium and subsequent eruption.
Despite over 25 years of study, CMEs remain poorly understood. Theories of CME onset have emphasized, variously, flare blast waves, magnetic buoyancy, instabilities in the streamer belt, loss of magnetic equilibrium in filaments, and flux emergence. Existing MHD models of CMEs are limited by numerical diffusion terms that are several orders of magnitude higher than coronal values, limiting the models' usefulness. Modeling field lines rather than the field itself eliminates numerical resistivity, both enabling studies that could be accomplished in no other way and also greatly reducing computational cost. We have already prototyped a simple force-free field line model. We will extend it to support more complex, data-driven systems and to include gravity, gas presure, and reconnection. our semi-empirical approach both addresses the problem of CME origin and yields a natural bridge between future LWS missions and predictive models that could run in quasi-real-time.
The scope of this proposal is limited to quasi-stationary simulations of the buildup and onset of CMEs. However, field-line based models are both extensible to full, time-dependent ideal MHD simulations, and useful for many other physical systems. The tools which we will develop have the potential to geneate breakthroghs in many other solar, heliospheric, and magnetospheric contexts relevant to LWS.

Farrugia, Charles / University of New Hampshire
An Assessment of the Feasibility of Predicting Major Geomagnetic Disturbances from Monitors in the Inner Heliosphere (0.5 AU)

A viable space weather tool must provide both timely and reliable predictions of major geomagnetic disturbances. Solar wind monitors positioned judiciously in orbit around the Sun at say ~0.5 AU are in principle capable of giving an advance warning of ~1.5-2.5 days of disruptive interplanetary configurations. However, it is crucial to ensure that the advantage of early warning be coupled with a knowledge of how these structures develop en route to 1 AU so as to be able to understand what properties these structures have when they reach Earth. Aside from a well-grounded knowledge of how the magnetosheath and the coupled magnetosphere-ionosphere system respond to various interplanetary triggers, an informed assessment presupposes improved further knowledge of the following: (a) correlation lengths (of both field and plasma) along the Sun-Earth line; (b) correlation lengths normal to the Sun-Earth line; (c) how interplanetary quantities known to correlate well with geomagnetic activity develop from 0.5 to 1 AU; (d) how (a) - (c) depend on the specific interplanetary configuration; and (e) on the system's history, i.e., whether the structures are transient or corotating; and (f) the number of monitors required to keep correlation values above a pre-assigned, able tolerance level. For this proposed preliminary quantitative assessment there are extensive datasets which we shall use. The Helios 1 and 2 probes collected magnetic field and plasma data and data on particles of cosmic ray energies in the inner heliosphere (0.3 to 1.0 AU) during a major fraction of a solar cycle, with usable data for the purposes of this proposal from end of 1974 to mid-1981. Helios data will be supplemented by data from the IMP and ISEE 3 spacecraft which were, at least for a good fraction of the time, returning data from near Earth. Measurement of magnetospheric disturbances will be obtained from archived data.

Fennell, Joseph F. / Aerospace Corporation
Energetic Radiation Environments in the inner Magnetosphere: Polar and HEO Data

We propose to update the energetic electron models of the Earth's radiation belts using data from the Polar and HEO energetic particle investigations taken during the period from solar minimum through solar maximum (mid 1994 to mid 2001). In addition we will include the extreme conditions and characterizations of the environment variability that are missing from the present models.
The NASA radiation environment models, AE8 and AP8, are used worldwide for engineering purposes. In spite of the obvious importance of these tools, the models are based upon data that is decades old. Studies have shown that the depth-dose profiles derived from AE8 are, in general, not accurate. Other deficiencies of the AE8 models include the fact that only omnidirectional fluxes are specified, that only long-term averages are available, and that the time dependence in these models is limited to solar max vs solar min. We propose to correct these deficiencies.
Accurate, long term averages of the space radiation environment are increasingly important as cost and availability considerations create pressure to use COTS (commercial, off-the-shelf) components. These do not have the radiation hardness pedigree of traditional space-use rad-had components. There is great scientific and engineering interest in knowing the variance of the space radiation environment from long-term average values. In particular, we need to know what the worst-case environments are. For example, what is the equivalent of a thirty or one hundred year storm? Worst case values are needed for purposes such as extra-vehicular activity (EVA) planning for Space Shuttle and International Space Station (ISS) missions, for developing hardening specifications and test requirements for spacecraft components, and for evaluating background effects in spacecraft systems. The radiation problems for ISS are spelled out in great detail in a National Academy Report (NRC, 2000) and those for unmanned spacecraft have been spelled out in a recent National Security Space Architecture report. We propose to respond to these needs by developing updated models of the radiation environment using new data from modern instrumentation.

Feynman, Joan / Jet Propulsion Laboratory
Prediction Techniquies for Solar Energetic Particle Event Onsets

The aim of this work is to improve our ability to give advanced warning of solar energetic particle (SEP) events that are hazardous to humans in space. This is also the stated objective of the LWS Human Exploration and Development Enterprise. It is well established that solar energetic particles are caused by very high velocity Coronal Mass Ejections (CMEs). A severe problem for the prediction of the high energy particles is that they propagate from their source (the shock accompanying the CME) to the Earth in a matter of minutes. Thus it is insufficient to simply observe that a fast CME has taken place. By then it is too late to predict the SEP with a lead time that will allow avoidance actions to be carried out. Instead we must develop the ability to predict the initiation of fast CMEs with an adequate lead time. Previous studies have identified solar conditions that presage CME eruption without regard for velocities (flares, sigmoidal structures, emerging magnetic flux etc.), but no studies have been made that relate pre-eruptive conditions specifically to the velocities of the subsequent CMEs.
Using data in the public domain, we will carry out statistical studies of the relation of CME velocities to pre-eruption conditions. This will be the first study that systematically studies the indications that a high velocity CME is imminent. As the first study of this central problem for advanced warning of SEPs, we expect it to result in significant improvements in our forecasting capability.

Floyd, Linton E. / Interferometrics Inc.
Characterization of the Time Series Behavior of Solar EUV Irradiances

We propose to study the solar EUV irradiance time series derived from the measurements of two instruments: the Solar EUV Monitor (SEM) and the EUV imaging Telescope (EIT) both aboard the Solar Heliospheric Observatory (SOHO). The SEM, a component of the Charge, Element, and Isotope Analysis System (CELIAS) experiment (Hovestadt, 1995), measures the EUV irradiance in two wavelength bands, 0.1-50 nm and 26-34 nm. After responsivity and its degradation have been accounted for, a standard spectrum was used to produce photon fluxes. The EIT images the sun at 4 distinct EUV wavelength bands centered on 17.1 nm, 19.5 nm, 28.4 nm, and 30.4 nm onto a 1K x 1K CCD (Delaboudiniere, 1995). After flat-fielding and other responsivity corrections, these images have been integrated to form irradiances. Further processing using emission measure modeling have yielded pure EUV line emission time series. The proposed research will be to analyze these time series along with a set of known EUV proxies (e.g F10.7 radio flux or the Mg II core-to-wing ratio) and other solar measurements (e.g. GOES x-ray flux). These analyses are expected to result in enhanced understanding of both the EUV flux which originates in the solar corona and transition region and of the behavior of instrument and algorithms used to produce these fluxes.

Friedel, Reiner / Los Alamos National Laboratory

Dynamic Inner Magnetospheric Energetic Particle Data and Model Synthesis

The harsh radiation environment in the inner magnetosphere up to geosynchronous orbit is of major concern to an ever increasing amount of space hardware. The energetic particle fluxes from these regions are of further concern to regions of low-Earth orbit such as occupied by the International Space Station, especially during disturbed conditions. While the average or quiescent conditions of the energetic particle population are fairly well characterized, the dynamics during magnetic storms are severely under-sampled. The underlying processes responsible for the large variability in the observed behavior of the relativistic electron component in particular, are still a matter of intense scientific debate.
We intend here to use a theoretical model (Salammbo) to extend and combine existing energetic particle measurements to interpolate in L and to extrapolate the energy range. Combining both measurements and model enables us to increase both the spatial and temporal resolution of the data, and allows us to define time-dependent maps of the radiation belts, both for now-casting and research purposes.
Salammbo is a sophisticated particle transport code which has been used successfully to reproduce the global radiation belt dynamics for energetic electrons and protons, using relatively few inputs such as geosynchronous data as a boundary condition and Kp. In the absence of other data inputs, Kp is used as a scaling proxy for radial diffusion, plasmapause location and wave activity. Salammbo also includes a small-scale recirculation process which has been used to model the dynamics of relativistic electrons. Data is from the DOE/DOD geosynchronous, GPS, HEO, and SAMPEX satellites, which carry energetic particle instrumentation and provide almost total coverage of the magnetosphere ranging in L from 1.1 to 8 and at altitudes from low earth to beyond geosynchronous. These spacecraft, all currently operational, provide nearly continuous data over periods of almost a decade. They form the first proper inner magnetospheric constellation and are an ideal testbed for future constellation-type missions such as envisioned by the Living with a Star Program at no operational cost.

Fuller-Rowell, Timothy / University of Colorado, Boulder
LWS Proposal to Provide Scientific Guidance and Modeling Support for the Ionospheric Mapper Mission

One of the potential benefits of the LWS Ionospheric Mapper mission is to be able to take advantage of the availability of "dual-altitude" constellations. The lower altitude (~450-km) LWS component comprising, predominantly, in-situ plasma and neutral instruments, and the higher altitude (~850-km) POES segment providing additional remote sensing instruments. This proposal will explicitly evaluate the merits of such a combination by targeting a specific science question.
Specifically, we will address the question: can low-Earth-orbit measurements of the "direct" response of neutral temperature and density be used to quantify the spatial and temporal variations of the high latitude magnetospheric sources? For instance, neutral

temperature changes, gravity wave surges and "holes" in neutral density, all reflect the strength, local time distribution, and temporal variability of the energy deposition. Utilizing these neutral response characteristics provides crucial information to adjust the output of the AMIE assimilative scheme, and so tune the specification of the sources. The study has two parts. The first is an extensive upgrade of the AMIE procedure. The second is the development of data assimilation tools, to enable LWS satellite observations of low-altitude neutral atmosphere structure to be combined with physical models of the upper atmosphere, to further constrain the high latitude input. The ability of the schemes to accurately specify the magnetospheric momentum and energy injection will be tested by quantitative comparisons of the model predictions with the observed global ionospheric and dynamic response, to geomagnetic events. The data assimilation approach will include the development of an adjoint physical model of the thermospheric energy budget, and will include an evaluation of the "ensemble" Kalman filter technique. In addition to providing the physical understanding and an improved AMIE assimilation tool, the outcome of the research will provide the rationale and guidance for the Ionospheric Mapper. The study will provide essential elements in the modeling requirements and data assimilation expertise, required for support of LWS.

Fung, Shing F. / NASA/Goddard Space Flight Center
Development of New-Generation NASA Space Radiation Environment Models

We propose to develop a set of new-generation NASA space radiation environment models to support the implementation of NASA Living with a Star (LWS) program and the National Space Weather Program (NSWP). To meet the increasing demands for different data products by distributed users in the diverse space research, space environment effects and engineering communities, a Center for Space Radiation Modeling (CSRM) will be established at the NASA Goddard Space Flight Center. The NASA CSRM will have prime responsibilities in data acquisition and management, and in constructing, validating and disseminating NASA space radiation models. It will interface with other NASA and non-NASA radiation data/models suppliers/users to ensure the long-term usability and accessiblity of the data and models. To that end, the NASA CSRM will fully exploit modularized object-orientation technology and standardized data formats to provide a common framework to support both scientific and engineering applications. Functioning like a container cargo dock, distributed users will be able to connect or dock at the CSRM facilities through standardized interfaces designed to receive and distribute information (data and software) and to access a full suite of data display and analysis (modeling) tools. In a network-operating environment, the interfaces will allow existing and upcoming independent systems to function seamlessly as a single one.

Funsten, Herbert O. / Los Alamos National Laboratory
Next Generation Ion Detectors for Monitoring and Analysis of Solar Disturbances and Their Effect on the Geospace Environment

Conventional silicon-based solid state detectors (SSDs) offer many benefits for use as particle detectors for solar wind and magnetospheric measurements, but they are limited to measuring high energy particles (>20 keV for H+ and higher for heavier species). We propose to develop and test a new type of low energy ion detector, called a hybrid photomultiplier tube (HPMT), that provides energy resolution, intrinsic noise, and sensitivity levels that are far superior to SSDs at low energies. For magnetospheric measurements, the combination of an HPMT and an electrostatic energy analyzer will enable clear mass resolution of H+, O+ (tracer species of the ionosphere), and He2+ (tracer for the solar wind) within highly constrained resources. For solar wind composition measurements, the HPMT will allow significantly improved mass and charge resolution while reducing the resources by at least 2 kg and 2 W. In this study, we will assemble an HPMT detector for detection of low energy ions and will investigate the key parameters that govern the detector performance by measuring and modeling the HPMT response as a function of ion species and energy. These measurements will be used to characterize the HPMT detector as the key enabling technology for minimum resource mass spectrometry of the magnetospheric and the solar wind plasmas.

Goode, Philip R. / New Jersey Institute of Technology
Earthshine Measurements of the Earth's Albedo

The earth's climate depends on the net sunlight absorbed by the globe, which is quantified by the earth's albedo. A global and absolutely calibrated albedo can be determined by measuring the amount of sunlight reflected from the earth and, in turn, back to the earth, from the dark portion of the face of the moon (the "earthshine" or "ashen light"). Such data provide a critical complement to satellite data.
We have been measuring earthshine since December 1998, and have already demonstrated that the earthshine can be observed with sufficient precision to derive meaningful information about the earth's optical reflectivity. We have measured 20% seasonal variations in the earth's global albedo.
We propose to continue these observations from Big Bear Solar Observatory (BBSO), and expand them to a three-station network that will give us global coverage. The albedo data will also enable us to quantitatively assess the global effects of secular and seasonal variations, as well as those of transient phenomena such as a volcanic eruption, El Nino or La Nina. During the three year period proposed here (2001-2004), we will obtain a data base covering solar activity maximum and the declining phase of the current cycle, enabling us to determine the level of solar cycle dependence of the albedo. We propose to continue our modeling of earthshine by using scene models developed for the Earth Radiation Budget Experiment (ERBE). We have already found shortcomings in its

averaging, which we propose to correct. Finally, we have begun seasonal observations of the earthshine spectra using the 60" telescope on Mt. Palomar and its Echelle spectrograph. We propose to use earthshine spectral data to search for the degree of large-scale changes in the earth's atmosphere, its structure and composition.

Goodrich, Charles C. / University of Maryland
Prediction of the Three Dimensional Structure of the Solar Wind at the Earth from L1 Orbit

We propose a two-year project to investigate how accurately observations from one or more spacecraft at the L1-halo orbit can predict the solar wind plasma and magnetic field just upstream of earth. By focusing on events in which solar wind observations from multiplespacecraft are available, we investigate these three basis issues: (a) what is the transverse, small (earth radii)-scale, steady-state and transient, structure of the solar wind near the earth, their properties, evolution, and interactions; (b) how does this structure propagate and evolve from L1 orbit to the earth, (c) can we reliably and accurately predict the solar wind at the earth from a single or more in situ measurements at L1. Our overall goal will be to recommend the optimal number and spacing of spacecraft in L1 halo orbits to provide accurate solar wind input for the LWS program.
The project will be based on both numerical modeling of the solar wind and analysis of solar wind observations from L1 (WIND and ACE) and near earth spacecraft (IMP 8, GEOTAIL, and Interball-tail). We will simulate the propagation of 3D structures from L1 to the earth and the reverse using a special implementation of the 3D MHD code developed by Odstricil. This code has been successfully used to investigate the interaction between transient disturbances with the background structures solar wind. The much smaller physical domain of interest here will enable use of very fine numerical spatial and temporal resolution. We will apply data assimulation techniques developed in meteorology to infer the transverse structure of the solar wind at L1 from the observations. This analysis will help to specify appropriate input data and evaluate importance of dynamic phenomena for the simulations. We will test and refine the structure at L1 by propagating it to the earth in the code.
Important results will be provided at the very beginning of the NASA LWS program in order to provide scientific background for the eventual incorporation of spacecraft constellation at the L1-halo orbit within the future space weather network.

Gopalswamy, N. / Catholic University of America
Propagation of CMEs through the interplanetary medium: Interactions with the Solar Wind

An empirical model to predict the arrival of coronal mass ejection was recently

developed using SOHO and Wind data. This model has been validated using archival data from Helios-1, Pioneer Venus Orbiter and P78-1 data. We propose to improve the model by correcting for projection effects in speed measurements and the variability of solar wind speed. Using theory and MHD modeling, we shall develop a physical understanding of the empirical model. We also propose to put the model into operation to iteratively improve the model.
This proposal is relevant to at least two of NASA's four Strategic Enterprises: Space Science and Human Exploration and Development. A reliable model to predict the arrival of CMEs and their associated shocks in the vicinity of Earth based on their origin at the Sun, is an important tangible advance; a successful model is a testimony to our understanding of the coupling between CMEs and the Sun-Earth connected space. Since most of the long-lived solar energetic particle events are due to CME-driven shocks, the prediction of the latter is highly relevant to human exploration and development in space.

Hagyard, Mona J. / NASA/Marshall Space Flight Center
A Search for Magnetic Field Signatures of Coronal Mass Ejections

The objective of this proposed program is to develop observational techniques in vector magnetometry for the identification of signatures indicative of potential coronal mass ejections. To carry out this objective we will obtain observations of vector magnetic fields in solar active regions using the Marshall Space Flight CenterÕs Tower Vector Magnetograph (TVM) that has recently been upgraded with a new CCD camera and data system. The data from these observations will be used in two newly developed analysis techniques that measure the global nonpotentiality of bipolar active regions: (1) length of strong-field and strong-shear main neutral line and (2) global net current. X-ray coronal images from the Yohkoh satellite will be analyzed for the presence of sigmoidal structures in these regions, and flare lists will be examined to determine the production of CMEs from them. The SOHO/LASCO lists of observed CMEs will also be used to locate the regions producing the CMEs. Subsequently, analyses will be carried out to determine the degree of correlation between the production of CMEs and the two new magnetic signatures as well as the sigmoidal signature. An initial study of four active regions has shown that each of these two new magnetic parameters is a useful indicator of an active region's likely CME productivity. It was also shown that these two parameters may be more reliable predictors than is the presence or absence of sigmoidal structure in coronal X-ray images. This latter result would be particularly useful since the morphological characterization of a sigmoidal signature is fairly qualitative in nature while the two parameters we propose are quantitative measures. Thus we are directly addressing the "Living With a Star" objective of finding reliable predictors of CME activity.

Ho, George / Applied Physics Laboratory

Interplanetary Shock Prediction Using Real Time Energetic Particle Observations

Interplanetary (IP) shocks driven by coronal mass ejections (CMEs) continuously accelerate ions to higher energies as such shocks propagate through the heliosphere. These ions can be hazardous to humans and technological systems in space. In particular, ions accelerated locally at the traveling shocks, the so-called energetic storm particle (ESP) events, can have intensities at energies >30 MeV that increase by several orders of magnitude. Although the basic physics underlying the shock acceleration process is well understood, no study has attempted to use observed ESP events to predict the arrival of the associated IP shock. The current shock prediction models, which are based on metric Type II radio emission use only the H-alpha location and X-ray duration, do not take into account the CME that is ultimately driving the shock. A better shock prediction model is needed to reflect the current understanding of CME/shock/energetic particle relationship. We propose a one-year effort to use the real-time energetic particle data along with solar wind and magnetic field data to examine all IP shocks from November 1997 to December 2000 and produce an empirically predictive tool. Based on this vast data set we will build a statistically based model to predict (a) the arrival time of an incoming IP shock, and (b) the maximum SEP intensity at Earth values measured upstream of the Earth.

Hurlburt, Neal E. / Lockheed Martin Solar & Astrophysics Lab
A Problem-Solving Environment for Living With a Star

The unique aspect of the Living With a Star program is its systems approach to understanding our space environment. For this approach to be successful, the program must start from the beginning as a unified system itself. A working environment that presents the LWS components as a unified whole is essential to keeping the focus on this system approach.

We propose a unique architecture and data assimilation environment which addresses this critical issue. Our Problem-Solving Environment for Living With a Star (PSELWS) places the data users at center stage -- providing a virtual workbench with the tools, and infrastructure needed for seamless, timely and efficient access to the various data sources. In this environment users will be able to form complex queries that far exceed the simple catalog searches of existing systems -- and thus receive only the data they require for their research, rather than being overwhelmed by irrelevances.

Our approach combines the substantial, existing software infrastructure developed for solar data analysis (SolarSoft) with state-of-the-art software agents for distributed computing. Our team members are all contributors to the key technologies and software involved in this effort. We are ready to focus our skills to develop prototype systems in time for the first LWS missions.

In addition the architecture and software elements developed through our proposed research will be useful throughout the Sun-Earth Connections theme, including the current suite of space instrumentation and those upcoming in the Solar-Terrestrial Probes line. And they will form an excellent foundation for educational and public outreach efforts.

Isenberg, Philip A. / University of New Hampshire A New Kinetic Model for Coronal Heating and Generation of the Fast Solar Wind by Ion-Cyclotron Resonance

The solar wind directly controls the properties of the Earth's plasma environment, as well as fundamentally mediating all the energetic plasma disturbances, from coronal mass ejections to cosmic rays, which affect our life and society. The heating and acceleration of the ions in coronal holes, which produces the basic fast solar wind, has been the subject of intense investigation for many years. The process which seems most likely to explain this heating is the cyclotron-resonant dissipation of ion-cyclotron waves. Many theoretical models incorporating this mechanism have been able to reproduce the fluid properties of the fast wind, but very little of this work has considered the detailed kinetics of this resonant interaction.

Recently, we presented a new analytical description of the kinetic response of collisionless coronal ions to the resonant cyclotron interaction. This 'kinetic shell' picture uses the reasonable assumption that the resonant response of the ions occurs much faster than the non-resonant processes in the corona. Our initial investigations of this assumption were very encouraging, and lead to a number of promising suggestions for modeling the generation and kinetic evolution of the fast solar wind.

Here, we propose a three-year project to develop a comprehensive quantitative model of the generation of the fast solar wind, using this kinetic shell formalism. We will undertake a series of well-defined steps to extend our initial calculations, adding in stages the effects of inward-propagating waves, dispersion, and heavy ions. Qualitative analysis has already shown that this model can produce a realistic fast wind with a minimum of free parameters, as well as detailed new explanations for the presence of the secondary proton beam and the preferential heating of heavy ions.

Ultimately, this model will provide rigorous tests of the resonant cyclotron heating mechanism, and will serve as a valuable operational tool to guide future observations. This understanding of the kinetic origins of the solar wind is a necessary foundation on which to build models and predictions of more complicated behavior of the heliospheric medium.

Jackson, Bernard V. / University of California, San Diego
Modeling Heliospheric Disturbance Propagation Using Remote Sensing Observations

Earth, immersed in the Sun's atmosphere and bombarded by solar high energy particles,

has no choice but to react to these inputs. We now know that the largest solar coronal disturbances, called coronal mass ejections or CMEs, are the cause of major geomagnetic storms, which can create hazardous conditions affecting satellites and astronauts in orbit, communications, and even ground-based systems.
At UCSD we have been at the forefront of remote sensing studies of the origins and propagation of CMEs, and their effects on geospace. We have developed a tomographic technique to track these disturbances outward from the Sun. We are also involved in the construction of the Solar Mass Ejection Imager (SMEI) to be launched in December 2001. At present there is no effective way to track interplanetary disturbances crossing the large gulf between the solar corona and Earth. If successful, SMEI will revolutionize the way we are able to measure heliospheric features and forecast their arrival at Earth by tracking CMEs from near the Sun until they strike Earth 2-3 days later. To understand and forecast how solar transients are produced and propagate, we need to study the origins, interplanetary propagation and signatures of CMEs, and to develop techniques to measure and model heliospheric plasma and disturbances from a global perspective. To accomplish these objectives we propose to: 1) Study CMEs and other solar plasma phenomena to better understand their origins, interplanetary propagation and how they interact with Earth's magnetosphere; 2) Develop heliospheric tomographic programs for use with existing and future data sets such as interplanetary scintillation and SMEI; and 3) Develop SMEI data-reduction techniques to provide images with the requisite 0.1% differential photometric precision required for tomographic analysis. Our proposed program is relevant to NASA's Sun-Earth Connection Theme and the techniques developed will be pertinent to future NASA space missions such as STEREO, Solar Orbiter, Solar Polar, and Solar Dynamics Observatory.

Jorgensen, Anders M. / Los Alamos National Laboratory
Magnetic structure and current signatures of storms and substorms

We are proposing to use historic data sets to explore the three-dimensional structure of magnetic fields and currents in the inner magnetosphere during storms and substorms. In previous work [Jorgensen, 2000, submitted] we used CRRES data to measure the configuration of the azimuthal ring current, including the total current, its spatial distribution, as well as the motion and asymmetry of the ring current as a function of activity as defined by Dst. In preliminary studies using CRRES and SCATHA data we found that it is possible to measure the weaker non-azimuthal currents as well as the signatures of substorms. We intend to use historic data from the CRRES, SCATHA, and DE-1 missions to (1) map the magnetic fields and current systems associated with magnetic storms, (2) map the magnetic fields and current systems associated with substorms, and (3) build analytical empirical models of these currents using empirical models from the literature as well as models we create inspired from the maps.

Kauffman, Billy / Space Environments and Effects (SEE) Program
Geospace Environment Variability and Implications for Spacecraft Design and Operation

This proposal comprises two modules. The first is to improve our scientific knowledge of the thermospheric environment conditions and variations over the solar cycle. The work is carried out in three parts: (a) Develop a comprehensive thermospheric database of neutral density variability necessary for validating new EUV proxies, (b) Improve current EUV proxies and upgrade neutral thermosphere response in semi-empirical models, and (c) Evaluate data fusion techniques to increase the specification capability of thermospheric models. The results of this work will significantly advance model descriptions of quantitative relations between the solar EUV spectrum and the response of the thermosphere, and will they permit global density specification to within 3% globally. These results will be directly applicable to satellite drag specification and forecast. The second module is to develop a high-latitude scintillation specification and forecast product. It will predict where irregularities - and hence scintillations - will occur based on tracing forward along convection trajectories the large scale structures and irregularities detected by satellite instrumentation. The needed convection information will be based on a combination of in-situ ion drift measurements, IMF driven global convection patterns, and HF radar measurements. The resultant predictions will be validated by comparing with scintillations observed from ground stations at several high latitude locations. The overall program management and coordination of this proposal will be performed by NASA's Space Environments and Effects (SEE) Program. This Program is customer-driven and product-oriented and is considered a "One-Stop-Shop" for providing environment specification models and effects tools by providing synergy and a seemly transition between modeling the environment and the effects due to the space environments. The SEE Program will manage the environment specification modeling effort of this proposal and coordinate the distribution of its product each year through the SEE website and to the Living With A Star Theory and Modeling Program.

Koons, Harry C. / Aerospace Corporation
Investigations of the Space Plasma and Space Radiation Environments Responsible for Spacecraft Charging

We propose to investigate a number of basic physical processes in the Earth's magnetosphere related to spacecraft charging. The proposal addresses the LWS objectives for Aeronautics and Space Transportation, which seek further detailed characterization of the radiation environments useful for the design of more reliable space systems. The goal is to achieve a scientific understanding of the fundamental plasma interactions and particle transport processes responsible for the extreme conditions that pose the most serious threat to space systems. The objectives are to provide (1) models that accurately characterize the space weather conditions that are responsible for spacecraft charging, (2) the space environment information required for spacecraft manufacturers and operators to make sound technical decisions concerning all aspects of spacecraft charging, and (3) scientific inputs for the LWS Magnetospheric Multiscale and Radiation Belt Mapper missions by identifying gaps in current data and knowledge. Data from a number of NASA, NOAA, U.S. Air Force and commercial spacecraft including SCATHA, CRRES, GOES, POLAR, and ICO are available for the studies. The recently recovered SCATHA particle and plasma data, the LANL energetic particle data, and the CRRES energetic particle data will be the primary data used for the investigations. We expect to improve the basic understanding of the interaction of plasma sheet electrons with a spacecraft, and the transport, production, and loss processes that determine the intensity of the radiation belts. We will emphasize the extreme storms that pose the most serious threat to spacecraft. We will determine the common characteristics of typical storms and look for exceptional characteristics of super storms. We expect to develop empirical models of plasma injections and energetic particle dynamics during and following large storms that can later be used to validate physical models of particle transport and energization.

Kota, Jozsef / University of Arizona, Tucson
Energetic Particles and the Earth's Environment in Space

Energetic particles are one of the most important elements of the Earth's environment in space. First, large increases in the flux of Energetic Particles reaching the Earth may pose serious threat to technology such as satellites and other parts of the human environment in space. Second, the mobile energetic particles offer a unique tool to probe the electromagnetic structure of the Sun-Earth environment.
This proposal seeks three years of support for a program of theoretical studies and detailed numerical simulations which combines and unifies these two aspects. We propose to use various techniques to model and predict impulsive and CME (Coronal Mass Ejection) accelerated gradual Solar Energetic Particle (SEP) events, as well as to explore and compare the accompanying variation the caused by the same plasma and magnetic changes on the flux of galactic and anomalous cosmic rays. Comparison of these simulation results with observations may advance our predicting capabilities.
Specifically we propose:
a) To develop numerical models to predict the energy spectra and time-profiles of CME accelerated SEP events. The code incorporates the time evolution of the shock driven by the CME, and that of the whole field configuration. b) To model the variation of galactic cosmic rays (Forbush decreases) caused by the same magnetic disturbance. c) To model transient events such as impulsive SEP events, transient shocks, etc. d) To study connections between the long-term changes in the solar plasma, magnetic field and cosmic-ray phenomena, to be used to understand the history of the earth's space environment.
We plan to develop and apply a new code for field-aligned transport, modify and adapt our existing 2- and 3-dimensional codes for the inclusion of transient events, such as

CMEs, as well as use our advanced particle pushing codes.

Lario, David / Applied Physics Laboratory
Solar Energetic Particle Events in the Inner Heliosphere and Deep Space: A Model for Forecasting Proton Fluxes and Anisotropies

Solar Energetic Particle (SEP) events pose a threat to spacecraft components, materials, and operations. Accurate models for their occurrence, flux profiles, and durations are an important component of space weather. SEP events originate at shocks driven by coronal mass ejections (CMEs) propagating through interplanetary space. Such models must simulate the shock propagation and the injection and transport of shock-accelerated particles. We have developed a model that incorporates these processes. We simulate shock propagation with a magnetohydrodynamic (MHD) time-dependent code, and energetic particle propagation by solving a 1st-order complete transport equation that includes the source of particles accelerated continuously at the moving shock. This model departs from previous particle prediction schemes in that we account for the continuously changing relationship of the observer to the propagating shock. The model reproduces 50 keV-20 MeV SEP proton flux and anisotropy profiles and provides a relationship between the MHD parameters of the shock and the injection rate of shock-accelerated particles. We will use this relationship to create a catalog of simulated SEP events to determine the acceleration efficiency of shocks and to predict the evolution of SEP events. In Year 1 we will build the catalog of SEP events at 1 AU simulated under different heliospheric conditions and configurations. In Year 2 we will extend this catalog to radial distances from 0.3 AU to ~2 AU to provide particle fluences for future NASA missions such as the Inner Heliospheric Sentinels. In Year 3 we will make our results available through the WWW and will study other possibilities for shock modeling and for the injection rate of shock-accelerated particles. Throughout this 3-year project we will build and update a data base of SEP events observed by ACE, IMP-8, Helios-1/2 and compare our calculated fluxes with SEP events in this data base. Our proposed work is central to NASA's Living With a Star program. We will model the evolution of SEP events at Earth and in the inner and outer heliosphere and provide a firm scientific basis for forecasting a key aspect of space weather.

Lean, Judith L. / Naval Research Laboratory
Can we Determine Long-term Solar Irradiance Variability from Terrestrial Geomagnetic and Cosmogenic Proxy Records?

The overall goal of the proposed research is an investigation of physical relationships between the Sun's irradiance and plasma energy outputs that influence historical proxies of solar activity recorded at or near the Earth. Explicitly, the relationships sought are

those between the closed magnetic flux regions on the Sun that produce irradiance variations and the open flux regions that control the solar wind which modulates terrestrial geomagnetic and cosmogenic indices of historical solar activity. Empirical associations between electromagnetic and plasma outputs from the Sun are evident in contemporary data, as are their mutual connections to the Sun's magnetic activity cycle. Since the observational record of solar irradiance exists for only two cycles, terrestrial proxies are essential to infer historical irradiance variations that may contribute long-term climate change. The present lack of understanding of the physical relationships between solar irradiance and terrestrial proxies impedes the reliable attribution of natural versus anthropogenic causes, and motivates the proposed work.
We propose to analyze and model space- and ground-based contemporary observations to establish the physical connections of radiant and solar wind processes with photospheric magnetic fields. We then will simulate the variability of open and closed magnetic flux caused by meridional flows, diffusion and rotation, and investigate how well these simulations can account for the observed radiative and plasma parameters, and the terrestrial proxies that they influence. Relevant space-based observations include solar irradiance and wind, and the interplanetary magnetic field. Ground-based observations include solar magnetic fields, sunspots and plages, and neutron fluxes generated by cosmic rays and geomagnetic indices. Perturbing the various transport, diffusion and rotation parameters in a manner consistent with speculated changes in the solar dynamo will them permit us to assess various scenarios for the impact of reduce solar magnetic flux, such as in the Maunder Minimum, simultaneously on solar irradiance, solar wind, interplanetary magnetic fields and the terrestrial pro

----

Liemohn, Michael W. / University of Michigan
Superposed Epoch Analysis of Ring Current Geoeffectivenss Related to Solar Wind and Plasma Sheet Drivers

It is known that the strength of the stormtime ring current is controlled by two driver functions: the convection strength (largely controlled by the interplanetary conditions) and the near-Earth plasma sheet intensity. The availability of interplanetary and geosynchronous orbit plasma observations over the past solar cycle provides a unique opportunity to investigate the relationship between these two driver parameters and the stormtime ring current. In addition, first-principle-based models of the hot ions of the inner magnetosphere have reached a level of sophistication allowing quantitative comparison with observations. Also, with the increased dependence of humanity on near-Earth space for communications, surveillance, and positioning, space weather prediction models are be-coming a necessity for reliable spacecraft operation. It is proposed to perform a superposed epoch analysis of the driver functions in relation to the attributes of the ring current (both observed and modeled) in order to better understand the connections between them. Many storms will be considered from 1989 to the present (more than a solar cycle), including an analysis of detailed kinetic modeling results of at least 20 of them (simulated for other projects). The expected outcomes from the proposed study are as follows: (1) specification of the relationship between solar wind drivers, inner plasma sheet characteristics, and ring current properties during magnetic storms; (2) examination of the dependence of geoeffectiveness on solar cycle; (3) determination of satellite spacing and instrumentation at geosynchronous orbit needed for accurate ring current modeling in space weather simulations; (4) improved prediction of the severity and duration of magnetic storms based on geosynchronous plasma observations; and (5) large-scale testing of statistical energy input functions against observed energy inputs to the inner magnetosphere.

Low, Boon-Chye / National Center for Atmospheric Research
Coronal Magnetic Structures Capable of Producing Coronal Mass Ejections

Observations and recent developments in solar magnetohydrodynamics have shown that Coronal Mass Ejections (CMEs) originate from the eruption of pre-existing long-lived coronal magnetic structures interpretable in terms of failure of confinement of highly twisted magnetic fields. This proposal seeks to understand the circumstances of such confinement failures based on analytical and numerical MHD calculations, and relate the theoretical results obtained to observations made in space and from the ground. Several sets of solutions describing static MHD structures in the unbounded space outside a sphere will be constructed, both in idealized axisymmetric geometry and in fully three-dimensional geometry in order to quantitatively survey the parametric limits within which equilibrium states may exist. The proposed work will provide theoretical understanding on (i) when magnetic-field confinement may fail in the solar corona, (ii) how much magnetic energy is available to drive a CME at such a failure point, and, (iii) what plasma and magnetic structures might be observed to be characteristic of such a confinement failure. This understanding will be fundamental to interpretation of existing NASA observational data on CME eruptions, with regards, in particular, to Space Weather interest in observational signatures of an impending CME eruption on the solar disk. The several MHD modeling groups in the solar physics community will benefit from using the static MHD solutions that will be generated by the proposed work as initial states to study CME expulsion out of the corona as time-dependent MHD flows in axisymmetric and 3D geometries. The success of numerical simulation depends on both the power of the time-dependent simulation code and on the availability of suitable initial states physically capable of evolving into a CME. The proposed work includes an observational component as well as a time-dependent simulation component, represented by the Co-Investigators of the proposal. The three-year funding requested will be for (a) the support of a graduate student to be appointed in the NCAR graduate fellowship program, (b

----

Luhmann, Janet G. / University of California, Berkeley

Coronal Models and Applications for LWS

Coronal magnetic field models have numerous applications, from investigating the genesis of CMEs, to predicting the arrival of coronal hole flows and interplanetary magnetic field sector boundaries at the Earth. For many years the potential field, spherical source surface model has provided a widely used tool for research and applications, leading to many insights and products. However, the corona is known to include currents, especially around active regions. Computational tools and capabilities in typical research institutions are now up to the task of using more physically correct approaches. We propose to investigate the capabilities of the publicly available 3D ZEUS code for coronal field modeling, and to test its application using solar magnetograph data as well as idealized photospheric fields for the boundary conditions. The results will be compared with the results for the same boundary conditions from the potential field source surface model, and with published results from other 3D MHD coronal models. A generally available and user-oriented MHD coronal model would possibly represent the next major step in coronal research and its applications. Our plan would be to develop and document the framework for a coronal version of the ZEUS code and the analysis of its results, and to deposit the tested version and framework and analysis codes at the CCMC for others' use. As a complement to this research, we also propose to develop a web-based 'Coronal Weather Report' lesson wherein a person can learn about the connection between the solar surface magnetic field and the appearance of the upper solar atmosphere, the corona, by choosing a photospheric field map and then viewing the coronal field model result.

Maynard, Nelson C. / Mission Research Corporation
Pre-noon Cusp and Boundary layers: Solar Wind Coupling to the Magnetosphere

The timing of merging of IMF magnetic field lines and magentospheric magentic field lines may involve significantly different lag times in each hemisphere because of the tilt of the phase plane as structures propagate toward the Earth in the solar wind. Recent results have shown that the cusp is bifurcated, with one side, which is connected to the small convection cell, being driven from merging in the opposite hemisphere. These studies showed that two-dimensional patterns from ground-based optical images of the cusp region can be separated relative to their source regions. This effectively separates spatial and temporal variations. The efficacy of these results depend to a degree on the antiparallel merging hypothesis. We will utilize correlations between Polar (during pre-noon overflights) and ground-based optics, SuperDARN radar measurements, ground-based ULF measurements, and DMSP. Solar-wind/IMF monitoring will be provided by Wind, ACE, IMP-8 or other ISTP satellites. We propose to determine when, where and under what conditions detailed structure in the solar wind and magnetosheath couples to the ionosphere (we anticipate that the coupling physics may be different away from the cusp), determine to what degree the small convection cell is driven from the opposite hemisphere, determine the thickness of and degree to which the boundary layer is open or closed, look for evidence of accelerated ions in the boundary layer and investigate their causes, and determine to what degree the Pc-1 and -2 oscillations are related to the low-latitude boundary layer ion dynamics. We will establish under what conditions the antiparallel merging hypothesis is dominant. We will compare the data driven results with large-scale MHD model results to key our interpretive thinking. This is a major building block for ionospheric convection models that are essential for describing geospace disturbances and predicting space weather effects, key elements of Living With a Star.

Onsager, Terrance G. / NOAA/SEC
Relativistic Electron Variability in Earth's Magnetosphere

This effort will determine the conditions in the solar wind and within the magnetosphere that are responsible for the strong variability in the relativistic electron flux in Earth's magnetosphere. We will use data from a six year period, slighty over half of a solar cycle, to evaluate the conditions leading to changes in the radiation belt fluxes, and to evaluate the radial and the local time dependence of the flux variations. Data that will be used include NOAA and LANL geosynchronous satellites, NOAA polar orbiting satellites, the GPS satellites, Polar, Geotail, Wind, and ACE. This research will not be limited to time intervals of strong geomagnetic storms, since considerable variability in the radiation belt populations is observed during weak storms or even during non-storm times. The observed dependence of the particle fluxes on local time, radial distance, and energy will be used to assess the relative importance of the enhanced ring current, tail-like magnetic field stretching, and magnetopause compression for causing the abrupt particle dropouts that are commonly observed. Measurements from the Geotail spacecraft will be used to assess the adequacy of particle heating in the near-Earth plasma sheet to account for the observed enhancements of the electron flux in the inner magnetosphere.

Picone, J. Michael Naval Research Laboratory
Application of New Solar and Atmospheric Variability Models for Forecasting Thermospheric Drag on Spacecraft: Starshine and Yohkoh Case Studies

The overall goal of the proposed work is to study and specify accurately the response of the neutral upper atmosphere to solar irradiance variations. A direct application of this work is improved forecasting of atmospheric drag on low earth orbiting (LEO) spacecraft, notably the International Space Station (ISS) and the debris which threatens the ISS. Varying solar energy inputs cause significant fluctuations in upper atmospheric temperature and density that impede the motions of earth-orbiting spacecraft. Knowledge of the instantaneous locations of orbiting spacecraft (and debris) is essential to support societal needs that include national defense, communications, spacecraft and space shuttle mission planning and astronaut safety.

The largest source of error in precision LEO orbit determination is the estimation of drag, primarily due to errors in the density model. Past studies indicate that the driver of these errors is inaccuracy of the F10.7 cm radio flux in representing the solar driver of the thermosphere. We will combine, for the first time, (1) new models of EUV irradiance variability developed recently at NRL (NRLEUV and the SOL-C index) and (2) NRLMSIS, an improved upper atmospheric composition and temperature model also developed recently at NRL. We will test and validate the new capability by comparing predicted and actual locations of the Starshine and Yohkoh spacecraft and by comparing the NRLMSIS atmospheric density values with those derived from the spacecraft orbits. A product of our work - an improved density model for predicting LEO spacecraft locations - has immediate relevance, for example, in reducing the time spent in collision avoidance maneuvers by the ISS. The more accurate empirical atmospheric model will also improve analysis of observations by important science missions (e.g., TIMED) and will embody a clearer picture of the Sun's effect on the near-Earth space environment.

Raeder, Joachim / University of California, Los Angeles
Solar effects on global climate due to cosmic rays and solar energetic particles

We propose to investigate the role of galactic cosmic radiation (GCR) and solar energetic particle precipitation in generating aerosols and cloud condensation nuclei (CCN) in Earth's lower atmosphere. This potential source of CCNs may affect the properties of clouds and hence the global radiation balance and climate. We will first model cosmic ray particle entry into the atmosphere by using a global model of Earth's magnetosphere--ionosphere--thermosphere system and particle tracing to obtain cosmic ray incidence rates. These will be used to calculate air ionization rates throughout the depth of the troposphere. We will then employ a novel model that simulates particle formation and evolution from molecular scales, typical of the ionized species produced by energy deposition, to the sizes commonly sampled in the lower atmosphere. This model's input consists of the air ionization rates, as well as the state of the ambient environment. Predictions regarding the size and composition of the particles over time will then be analyzed for potentially significant effects. In the proposed work we will: 1. Produce detailed maps of cosmic ray induced ionization in the troposphere for different levels of geomagnetic activity; 2. Connect the formation rate of ultrafine aerosols and CCN to the deposition rate of GCR solar particles for a range of background atmospheric conditions; 3. Investigate the sensitivity of aerosol production to solar variability on time scales ranging from hours to the 11-year sunspot cycle; 4. Compare predicted signals in atmospheric aerosol properties with reported changes in climatic parameters, testing the significance of possible correlations between solar variability and climate change; 5. Develop parameterizations that describe CCN as a function of solar state, and ambient conditions, for use in more detailed cloud and climate modeling studies.

Reames, Donald V. / NASA/Goddard Space Flight Center
Modeling the Acceleration and Transport of Solar Energetic Particles

We propose to build a more-quantitative model of solar energetic particle (SEP) events that can re-late the energy spectra and intensities of the SEPs to the properties of the CME-driven shock wave. Large SEP events are a significant hazard to astronauts outside the Earth's magnetosphere; they also damage electronic equipment, solar cells, and X-ray mirrors in space and affect terrestrial communications and the chemistry of the upper atmosphere. Recent theory of SEPs based on interaction with self-generated waves has been extremely successful in understanding SEP intensities, spectra, abundances, and anisotropies. Measurement of these properties early in an event may be used to predict subsequent behavior, especially for the intensity peak at the oncoming shock. We will analyze data from the Wind, IMP-8, Helios, and ACE spacecraft in large SEP events and test the developing theoretical model against these observations.

Retterer, John M. / Air Force Research Laboratory
Three Dimensional Model for Equatorial Ionospheric Bubble

Upwelling of lower-density plasma as the result of plasma instabilities creates plumes and bubbles in the equatorial ionosphere after sunset. (They also arise as a consequence of penetration electric fields during magnetic storms.) Plasma turbulence in the vicinity of these structures causes radio scintillation that interferes with communication and navigation (GPS) systems. These phenomena have been studied in the past in an idealized way, following the evolution of the plasma strictly in the equatorial plane in a two-dimensional model, using a static background ionosphere.
We have recently introduced a time-dependent background to the model, and allowed global-scale electric fields to be imposed, to better study the onset of the instability and its nonlinear evolution. We propose to generalize the model to three dimensions, including the variation along the geomagnetic field lines, to explore the structure of the bubbles.
With this model, we will be able to answer the important question of how far the bubbles extend in the north-south direction, and thus better estimate the volume of space occupied by these bubbles.
This work is relevant to several themes in the Living with a Star initiative, particularly the problem of geospace disturbances. A better understanding of the phenomena of equatorial bubbles is essential for predicting the impact of these phenomena on communication and navigation systems that rely on radio propagation through space.
The scientific understanding that follows will help us interpret the data from earlier NASA missions, e.g., San Marco, as well as upcoming missions such as CHAMP, the joint Air Force-NASA CNOFS mission, and the planned LWS GEC (Geospace Electrodynamic Connections) mission.

Rind, David / Goddard Institute for Space Studies
Spatial Footprint of Solar Direct and Indirect Radiative Forcing during the Past 400 Years

This proposal builds on time-dependent simulations already conducted of the response to forcing by the full solar spectrum for the past 500 years with a coarse grid troposphere-stratosphere model. We propose to make a detailed comparison of three different times that include both pre and post-industrial environments (circa 1670, with estimated low solar irradiance; 1890, with moderate solar forcing but prior to large trace gas increases and availability of some instrumental record; and 1990, with high solar irradiance and increased trace gases - but prior to Pinatubo). New simulations of the climatic response to the varying solar spectrum (0.1 to 100 microns in 190 wavelength bands) will make use of initial and boundary conditions generated from the appropriate time of the full 500 year run, but employ (1) a finer resolution atmospheric GCM (including the middle atmosphere), (2) calculated ozone response, and (3) a dynamical ocean model. Comparisons will be made between the temperature footprint associated with direct solar irradiance variations, and also the indirect effect of planetary wave response to ozone-induced heating. The relationship of these results to observed temperature changes will be examined. In this way we hope to gain a detailed understanding of the importance of natural solar-induced climate change on regional scales corresponding to the adopted level of irradiance change (0.2% total from the Maunder Minimum) and allow it to be separated from anthropogenic effects.

Roble, Raymond G. / National Center for Atmospheric Research
Studies of Solar-Terrestrial Influences Using a Whole Atmosphere Community Circulation Model

The NCAR Whole Atmosphere Community Climate Model (WACCM) is a global model of the entire atmosphere from the ground-to lower thermosphere (140 km) that has been designed to investigate solar-terrestrial coupling and climate issues. The model will eventually extend to 500 km. The model is an integration of three proven and well tested models, 1. The NCAR Climate Systems Model (CSM), 2. the NCAR Thermosphere - Ionosphere - Mesosphere - Electrodynamics General Circulation Model (TIME-GCM) and 3. The Model for Ozone and Related Chemical Tracers (MOZART). The WACCM has now been successfully run for over a year. We propose to use this coupled chemical/ dynamic model to investigate solar-terrestrial couplings throughout the entire atmosphere. It will use measured solar UV fluxes and variable auroral inputs to drive the model and the results will be compared with UARS, TIMED and other satellite and ground-based data. It will be used to investigate how deep into the highly variable Earth's atmosphere do solar-terrestrial effects penetrate and determine whether they influence climate and global change processes.

Ruohoniemi, J. Michael / Applied Physics Laboratory
A Statistical Model of High-Latitude Convection Referenced to Auroral Boundaries

The interaction of the magnetized plasma of the solar wind with the Earth's magnetic field is an important source of Sun-Earth coupling. The transfer of energy and momentum to the magnetosphere and ionosphere gives rise to disturbances in geospace that disrupt technological systems. To understand these processes, accurate models of the global distribution of electric field are needed. We propose to develop a statistical convection model that will utilize information on auroral boundaries to greatly improve on the accuracy that is currently available. The convection velocity measurements will be provided by the HF radars of the Super Dual Auroral Radar Network (SuperDARN). The Ultraviolet Imager (UVI) instrument of the Polar satellite will provide global snapshots of auroral luminosity, from which information on auroral boundaries can be derived. The IMF conditions imposed on the magnetosphere will be determined from measurements made at upstream satellites (ACE, Wind, IMP8). The velocity data are to be sorted by IMF conditions and processed in a coordinate system defined by the poleward edge of the UVI luminosity. The mapping to this coordinate system essentially orders the velocity data according to the auroral geometry. The model will greatly improve on the mapping of structure in the convection patterns by reducing the smearing of features that results from auroral variability. The new patterns will show the spatial relationships between the distributions of electric fields and precipitating particles and lead to an improved understanding of coupling processes. We will map the model patterns into the magnetosphere. The convection model and related products will be distributed freely via the JHU/APL SuperDARN web site.

Russell, Christopher T. / University of California, Los Angeles
Solar cycle variation and multipoint studies of ICME properties

The proposed effort directly addresses the objectives of the Living with a Star Program by studying the interplanetary manifestation of coronal mass ejections (ICMEs) at two radial distances from the Sun over a full solar cycle at each location. This study calculates the size, number, flux content, orientation, twistedness, and balance of forces of all rope-like ICME structures through the solar cycle and relates these measurements to the coronal magnetic structure at the source surface and changes in that magnetic flux. In addition the study exploits the availability of measurements from NEAR above the limbs of the Sun as seen by SOHO (quadrature studies) to relate the magnetic structure of ICMEs to the coronal properties of the causative CME. Also it utilizes available multipoint measurements of ICMEs to improve our understanding of the geometry of these structures and in particular their azimuthal elongation. All inversions of the data are performed with a non-force-free model. The inversions using multipoint measurements assume a non-cylindrically-symmetric field structure. Sufficient pilot studies have been undertaken to test the software and show the strong correlation of the resulting magnetic rope properties with the solar magnetic field structure. This effort will directly benefit the operation of the Stereo mission and will provide support for the thesis research of UCLA ESS graduate student Elizabeth Jensen. Finally this effort enables the creation of a website that provides easy access to the PVO and NEAR data used in the study.

Schlesinger, Michael E. / University of Illinois, Urbana-Champaign
A Troposphere-Stratosphere-Mesosphere General Circulation Model Study of the Effects of Electron Precipitation on Atmospheric Chemical Composition and the Tropospheric Weather/Climate System

The global climate/weather system can be affected by solar variability directly via the changes of insolation or through numerous indirect mechanisms that can change the chemical composition, temperature and circulation in the middle atmosphere, as well as by changes in cloud formation, the atmospheric electrical-circuit system and biospheric processes. Using statistical methods, Labitzke and Van Loon (1988, 1989, 1990) found a high correlation between solar activity indices and temperature and pressure fields in the troposphere and stratosphere. One proposed mechanism which may explain this correlation has been described by Hines (1974). He suggested that the solar-induced temperature and wind changes in the upper and middle atmosphere may result in changes in the phase and amplitude of planetary waves in the troposphere which, in turn, modify the weather/climate system. However, in recent experiments with 3-D models by Haigh (1996) and Shindell et al.(1999), it was shown that the variation of UV flux during the 11-year solar cycle could only produce an atmospheric response which is much smaller than the reported observations. There are other natural phenomena related to the 11-year solar cycle, however, which may affect stratospheric ozone. Callis et al. (1991, 1996, 1998) showed that the fluctuation of high-speed solar wind streams during the 11-year solar cycle would modulate the continuous precipitation of energetic electrons ($E > 5$-10 keV) into the lower thermosphere and mesosphere. They also showed that such energetic electron precipitation (EEP) events can lead to significant increases in NOy in the middle atmosphere, that NOy formed by such events is transported into the stratosphere, and that stratospheric reactive nitrogen oxides and ozone concentrations may be affected on a significant scale. It is potentially very useful to estimate the influence of the thermal and wind changes of this coupling on the climate/weather system.
Accordingly, we propose to study the effects of the variations of EEP events during the 11-year solar cycle on the ionization events in the middle atmosphere, the resultant NOy production, and the weather/climate system

----

Schrijver, Karel J. / Lockheed Martin Advanced Technology Center
A VIRTUAL SOLAR LABORATORY: AN INTEGRATED MODEL TO STUDY THE MAGNETIC ACTIVITY OF THE SUN

We propose a 3-year project to develop a numerical laboratory for solar activity. This will enable the first comprehensive simulation of all photospheric magnetic field that is involved in outer-atmospheric heating and in spectral irradiance changes. Coronal-field extrapolation and model loop atmospheres will be integrated into the code. We will also add field-line rendering and loop-visualization modules. The system will enable quantitative analyses of the entire non-linear and non-local system through comparisons to solar and stellar data to test our model for the full range of magnetic activity. We have three primary research goals. First, to simulate the solar field throughout the history of the Sun; this is used as input to explore the evolution of, e.g., solar spectral irradiance, global dipole field, and activity subject to magnetic braking. Second, to identify the most likely candidate(s) for coronal heating of the quiescent corona, by comparing observations to visualizations of model coronae based on different heating mechanisms. Third, to simulate the spectral irradiance throughout solar history; this is used to validate our results using solar and stellar data and as input to other LWS research topics. The team has extensive expertise in photospheric and coronal studies, in the solar-stellar connection, and in the physics of the upper Earth atmosphere. The segments of the code exist (each already having yielded interesting results), but need to be extended, optimized, and interfaced for efficient, comprehensive simulations. The code will allow coupling to SolarSoft IDL, and with C routines for speed; it will be documented and made available on the web for use by other LWS projects and by stellar physicists. We will actively coordinate with other LWS projects to catalyze our understanding. Simulated images and explanations of the results will be made available on the web (also in Spanish), and published in popular science journals.

Share, Gerald H. / Naval Research Laboratory
Solar Influence on Energetic Particles Impacting the Earth's Atmosphere

We propose to use gamma radiation to study the impact of energetic particles on the earth's atmosphere and to monitor the geomagnetic cutoffs for solar energetic particles. The gamma radiation is composed of bremsstrahlung, annihilation radiation, and nuclear lines from interactions of cosmic rays and solar energetic particles (SEP) with the atmosphere. The atmospheric gamma-ray emission varies with geomagnetic latitude, the solar-modulated cosmic ray flux, and the intensity of solar energetic particles. Atmospheric emission increased by over three orders of magnitude during the intense solar particle event of 1989 October 20. We propose to use archival gamma-ray data from the Solar Maximum Mission (SMM) and new data from the High Energy Spectroscopic Imager (HESSI) in this study. We specifically propose to: 1) determine the spectrum of protons impacting the atmosphere during the October 20 event and compare it with the spectrum measured by GOES (this provides information on particle transport in the magnetosphere); 2) study gamma-ray emission from weaker SEP events and determine the geomagnetic cutoffs; 3) study the relationship between solar activity and electron precipitation >15 keV; 4) study solar cycle variations of atmospheric gamma-rays and thermal neutrons; 5) study geomagnetic latitude variations of atmospheric gamma-rays and thermal neutrons; and 6) determine the origin of the highly variable 7Be concentration in the upper atmosphere. These studies have the goal of providing the foundation for a remote system that will monitor the energetic particle environment in the upper atmosphere and the geomagnetic cutoffs for solar energetic particles. Such a system can provide real time warning for astronauts and for passengers on commercial and military flights at high latitudes.

Shea, Margaret Ann / University of Alabama, Huntsville
Historical Evidence for Major Solar-Terrestrial Outbursts for the past 150 Years from the Analysis of Nitrate Data in Polar Ice Cores

The objective is to ascertain from historical data the probability of major solar-terrestrial events that had a significant proton flux for the past 150 years. Our most recent analysis supports the supposition that major solar proton fluence events (those with >30 MeV omni-directional fluence exceeding 109 cm-2) generate sufficient NOy in the upper atmosphere so that when the polar vortex is operating the resultant NOy is deposited in the polar snows. Magnetic records exist indicating major solar-terrestrial activity for the past 150 years. We propose to analyze the nitrate records to compare the NOy deposition in the years when major magnetic storms have occurred against the nitrate record in polar snows deposited within a few months of each event. The results of this study are appropriate to three of the four LWS NASA Strategic Enterprises.

Skoug, Ruth M. / Los Alamos National Laboratory
Determination of solar wind correlation scales using upstream solar wind observations, the implications for space environment forecasting: how many spacecraft and where do we put them?

Solar wind variations and transient events are the drivers of geomagnetic disturbances which can affect technological systems. A reliable space weather forecasting system will require monitoring of the solar wind conditions upstream of Earth, but the optimal location or locations for such monitoring have not yet been established. Previous and ongoing missions provide a great deal of multipoint data on the upstream solar wind. We will used these data sets to address a number of questions concerning the positioning of a solar wind monitor, including: Over what distance can an upstream monitor reliably predict behavior at a downstream monitor under various solar wind flow conditions? Can a single point monitor provide adequate determination of the orientation of solar wind fronts? A number of existing studies have examined the linear correlation coefficient between pairs of spacecraft, but this technique is a poor indicator of agreement whenever conditions are not rapidly changing. We propose to develop new tools for relating the measurements at multiple upstream spacecraft, including measurements from three spacecraft.

Smart, Don F. / University of Alabama, Huntsville
Changes in Geomagnetic Cutoff Rigidities over a 400-Year Interval

We propose to determine the change in geomagnetic cutoff on a world wide basis over a 400-year interval from 1600 to the present. The geomagnetic field is recognized to be changing (i.e. decreasing) over the present epoch of human history. These changes are non-uniform over the surface of the earth. While a crude representation may be accomplished by considering only the dipole changes, we propose a better representation by utilizing higher order simulations of the geomagnetic field to calculate the geomagnetic cutoff rigidities from 1600 to the present. Our present work shows that over the 400-year time interval the change in cutoff rigidity is sufficiently large so that the change in the cosmic radiation flux impacting the earth is approximately equal to the relative change in flux over a solar cycle. Presuming the work of Svensmark and Friis-Christensen is correct, that the change in the cosmic ray intensity over a solar cycle affects the cloud cover, then an equivalent change over a 400-year period should have similar importance on the long-term climate effects.

Suess, Steven T. / NASA/Marshall Space Flight Center
MHD Streamer Structure: Slow Solar Wind, the Streamer Brightness Boundary, and CMEs

Coronal mass ejections (CMEs) are studied because they are massive expulsions of plasma from the Sun and the main cause of non-recurrent geomagnetic storms. Moreover, most major terrestrial energetic proton events are the result of particle acceleration at shocks driven by CMEs. CMEs are caused by magnetic activity ejecting mass from low in the solar atmosphere that sweeps up material from the corona Ð streamer material. However, ejections are sometimes contained by the overlying corona. In other words, properties of CMEs depend on properties of the overlying corona. A dependence also exists for energetic particles because properties of coronal CME-generated shock waves depend on properties of the ambient medium which can enhance or preclude shock formation.
We propose to study the dependence of CMEs on streamer properties and develop ways to use existing observations to better predict CME properties. This is meant to be distinct

from studying the origin of CMEs. We will use models to investigate the likelihood that ejections will carry away overlying streamers. We will examine dependence on streamer size, history, density, and temperature and on the ambient outside streamers. We will develop models of the streamer ambient and show where and when strong shocks are formed in front of CMEs and hence where energetic particles are produced. Streamer size, history, density, and temperature will be used as the defining parameters because some or all of these are measured from SOHO and Yohkoh and will be measured from GOES/SXI, STEREO SDO, and Far Side Sentinal. Our goal is to develop techniques to apply underutilized empirical parameters to better predict consequences of CMEs, as opposed to the initiation of CMEs. We will base our research on a semi-analytic model which we will use for perturbation studies and modeling streamer environment. It will be a more powerful tool for parametric studies than existing numerical models. The model will address specific ideas for the origin of slow solar wind, the physical interpretation of the streamer brightness boundary, and the formation of CMEs as a consequence of magnetic activity near the base of streamers.

Tobiska, W. Kent / Federal Data Corporation
Solar irradiance forecasting, data assimilation, and visualization

Our proposed research has two objectives. Their successful completion will significantly advance our understanding of the "space weather" component of the Sun-Earth connection, including an improved set of measurement requirements for future LWS space missions, and will provide the conceptual basis for a new operational forecasting tool. The specific objectives are:
1) perform a scientific parametric study to determine if a phenomena of "thermospheric weather" exists and, if so, describe the range of its implications for the operations of space systems; and
2) develop and validate the elements of an operational solar irradiance forecasting tool applicable to space systems.
In looking at thermospheric weather, we will parametrically investigate the two effects. These are the heating of the thermosphere upper boundary during five time scales of solar variability (1-72 hours large flare periods, 3-14 days Earth-facing disk irradiances, 14-30 days solar farside events, 1-6 months active region evolution and decay, and 1/2-11 year solar cycle variability) and the secular cooling from increased carbon dioxide and methane (anthropogenic) radiators at the lower thermospheric boundary. The combination of increased heating at the top and increased cooling at the bottom should generate a stronger temperature gradient and affect turbulent and eddy diffusion in the lower thermosphere, hence, "thermospheric weather." We will not investigate the effect of dynamics in this study. A second result of this thermospheric parametric study will provide the conceptual basis for forecasting on five time scales. We will develop algorithms that quantify the variability in each time scale and these algorithms can be used for forecasting solar irradiances in space system operations. The programmatic relevance encompasses two NASA Strategic Enterprises (Space and Earth Science)

related to LWS. The proposed work will develop techniques (not time scales) related to both Enterprises. Included in these these techniques are demonstration of a unique solar irradiance forecasting concept, demonstration of a data assimilation and visualization technique, investigation of global climate change ef

----

Tsyganenko, Nikolai A. / Raytheon ITSS
Living With a Star: Global Modeling of Near and Distant Geomagnetic Field, Based on Magnetospheric and Interplanetary Data

The goal of this project is to develop a practical and realistic quantitative model of the geomagnetic field, valid in the entire geospace from low altitudes to the magnetospheric boundary and the distant magnetotail. The model will be based on the largest set of magnetospheric and solar wind data ever used, provided by many past and present space missions, and covering a wide range of interplanetary conditions, observed over more than two solar cycles. This effort is supposed to bridge the gap between the models of Earth's internal (IGRF) and external magnetic field. The model will replicate the observed variability of the magnetospheric configuration in response to varying solar wind conditions. Among its practical uses will be a short-term prediction of the penetration and cut-offs of the solar energetic particles, affecting low-altitude space technologies and the safety of manned missions. The proposed research will also benefit the development of future LWS missions, aimed at assimilating simultaneous data from constellations of spacecraft. Combining such data with flexible models by means of fast-fitting algorithms would make it possible to dynamically reconstruct varying magnetospheric configurations and provide instantaneous "snapshots" of the global magnetosphere.

Tylka, Allan J. / Naval Research Laboratory
Modeling Geomagnetic Cutoffs for Solar Energetic Particle Hazards on the International Space Station and Other Spacecraft

A recent report from the National Academy of Sciences, entitled Radiation and the International Space Station: Recommendations to Reduce Risk, identified the need for accurate "mapping [of] the latitudes to which [solar energetic] particles can penetrate under a variety of geomagnetic conditions to the altitude of ISS" as a "crucial project … deserving the earliest possible attention"… "because its potential impact on radiation risk reduction". In recognition of this need, the ROSS-2000 NRA specifically mentions "models of the near real-time latitudinal cutoff of solar energetic particles" among the objectives of the LWS/DATM program. In response to these needs, we propose to develop new models and software tools for evaluating the near-real time geomagnetic cutoffs, based on numerical integration of particle trajectories through semi-empirical models of the near-Earth magnetic fields. We further propose to validate our models by comparison with high time-resolution (<10 seconds) solar energetic proton and alpha observations from NOAA/TIROS in 1989 and from SAMPEX in 1992-2000.

Ulrich, Roger K. / University of California, Los Angeles
Time Dependence of Solar Magnetic Fields

We will address the needs of the Living With a Star program in the area of Space Science using observational methods and models of the sun's magnetic field configuration available from MDI, TRACE, the Mt. Wilson Observatory and other ground-based observatories. We will study the variability and disturbances of the field strength and configuration on time scales from hours to decades in order to:
1) learn the nature of the readjustment of the Sun's field which takes place during a CME,
2) establish better methods of predicting the solar wind speed and magnetic field orientation and
3) establish an improved long-term magnetic field strength database for application to the study of the evolution of the total solar irradiance during the 20th century.

To address these goals we will:
1) correct for mirror polarization in the Mt. Wilson database,
2) intercompare magnetic field measurements made by MDI, Mt. Wilson, the Wilcox Observatory and the National Solar Observatory,
3) study the effect of transverse magnetic fields on the potential field source surface calculation,
4) carry out CME retrospective studies and CME campaign observations,
5) develop predictive methods for treating the unseen side of the Sun's surface,
6) make regular observations of the saturation free line at $\lambda 523.3$ nm and
7) organize and host a magnetogram intercomparison workshop.

----

von Rosenvinge, Tycho / NASA/Goddard Space Flight Center
The Relationship between Solar Magnetic Field Changes on Various Time-Scales, Geomagnetic Activity and Energetic Particles

Geomagnetic indices have been used in studies of solar-terrestrial connections for many years. For example, the long-term variation of the yearly-averaged aa index has recently been used to argue that the solar magnetic field has increased by 130% in a short period of time - the last 90 years. However, long-term averaged indices are not simple to interpret because they contain the summed contributions to geomagnetic activity from different types of solar wind structures. Furthermore, the different indices (e.g., ap, aa, Dst) reflect different aspects of the response of the magnetosphere to these structures. These indices provide the only information available to study solar wind-magnetospheric interactions over an extended period. Thus, it is important to re-investigate what geomagnetic indices can tell us about solar wind structures and the long-term global evolution of the solar magnetic field, and also their limitations. Such studies are particularly timely because of our improved understanding of the importance of coronal mass ejections to geomagnetic activity and improved ability to recognize these structures in the solar wind. Recently, we have made a preliminary examination of the contributions of coronal mass ejections, corotating streams from coronal holes, and slow solar wind to the aa index throughout solar cycle 21. We showed that one of the commonly held beliefs about the double peak in geomagnetic activity around solar maximum is not correct. We plan to extend this study to additional intervals, and attempt to use the results to examine the geomagnetic indices during the pre-spacecraft era for signatures of these various structures. We also plan to investigate the occurrence rate of large >10 MeV particle events, in particular how high particle intensities originate through a solar cycle and to what extent event intensity-time profiles can be used as a forecasting technique. This study will use archival data from Goddard experiments on spacecraft extending from the mid-1960's to present.

Wang, Yi-Ming / Naval Research Laboratory
Empirical Constraints on the Initiation, Propagation, and Structure of CMEs

OBJECTIVES: We will use observations to constrain the initiation processes, near-Sun velocities, and 3-dimensional structure of CMEs. Questions to be addressed include: (1) To what extent can filament eruptions be associated with prior changes in the photospheric field distribution (e.g., with emerging flux)? What is the empirical relation between CME eruptions and multipolar magnetic topologies? (2) Do the various components of a CME have systematically different velocity profiles near the Sun, and is there evidence for a background component which does not reach escape velocity? (3) Can the observed structure of white-light CMEs be represented by flux ropes? What is the basic topology of the ejected filament (when present)?
PROCEDURE: We will identify filament eruptions using SOHO/EIT and ground-based H alpha observations, and search for prior flux emergence in MDI and NSO magnetograms. We will use source surface extrapolations to determine the large-scale coronal field topology above the filament before and after the flux emerges. (2) A previously developed algorithm allows us to record automatically the height-time trajectories of coronal material in the SOHO/LASCO C2 and C3 fields of view. We will extend the algorithm to process C1 and EIT images, thereby obtaining accurate constraints on the dynamics of CMEs very close to the Sun. (3) We will identify flux ropes and other large-scale structures in white-light CME images and deduce their 3-dimensional geometry using simple trial density distributions. We will identify the white-light counterparts of filaments and compare their morphology with existing models for prominences.
RELEVANCE: By elucidating the structure, origin, and dynamical properties of CMEs through data analysis and semi-empirical modeling, the proposed work will contribute to

the development of space weather prediction capabilities. The results will also be relevant to the future NASA STEREO mission.

Warren, Harry P. / Smithsonian Astrophysical Observatory
The Development of a New Model of Solar EUV Irradiance Variability

The Sun's extreme ultraviolet radiation (EUV, 50-1200 A) exerts a powerful influence on the Earth's upper atmosphere. Variations in solar EUV radiation drive significant changes in the density and ionization of the Earth's thermosphere and ionosphere. These changes affect the performance of ground and space based communication systems and spacecraft in low Earth orbit.
Because of the limitations of existing irradiance data and the empirical models derived from them, we have recently developed a new model of solar EUV irradiance variability that is independent of irradiance observations. Our model is based on intensities calculated from emission measure distributions, a simple model of limb-brightening, and analysis of full-disk solar images.
The initial comparisons between calculations from our model and existing irradiance data have been very encouraging. For example, our model predicts irradiances for many chromospheric, transition region, and coronal emission lines that are generally consistent with a recent, well-calibrated EUV irradiance observation. Our model can also reproduce much of the rotational modulation evident in the Atmospheric Explorer E (AE-E) irradiance observations near solar maximum.
The AE-E irradiance data, however, generally show significantly more solar-cycle variability than is evident in our modeled irradiances. Our model also predicts irradiances for some optically thick emission that are inconsistent with other irradiance observations. Finally, at wavelengths shorter than 170 A our model predicts irradiances that are much smaller than those that have been observed.
We propose to resolve these fundamental issues by incorporating observations from the CDS and SUMER spectrometers on SoHO, SXT on Yohkoh, and the Big Bear Solar Observatory into our model. Our primary objective is to use spatially resolved spectra to construct new emission measure distributions and to establish relationships between these emission measure distributions and the intensities observed in the full-disk images. This will allow us to make much more accurate calculations of the solar EUV irradiance at all temporal scales.

Webb, David F. / Boston College
The Magnetic Structure of CMEs: A Comparison of Halo CMEs with Magnetic Clouds at 1 AU

Solar disturbances produce major effects in the corona and the heliosphere. The largest of these disturbances, coronal mass ejections or CMEs, cause major geomagnetic storms at Earth. This proposed research will focus on study of the solar origins and heliospheric characteristics of the magnetic structure of those CMEs which are geoeffective. Thus, it is directly relevant to NASA's LWS program. The primary data sets for this study will be the halo CMEs observed by the SOHO LASCO coronagraphs and associated magnetic clouds or flux rope-like structures observed by the Wind spacecraft at 1 AU. We will examine the nature of the interplanetary magnetic structures responsible for major geomagnetic storms by comparing LASCO halo CMEs with flux rope-like structures observed with the Wind MFI experiment. From early 1996 through 1998 about 25 magnetic clouds were observed at Wind and most were associated with halo CMEs. The MFI data will be used to fit the magnetic cloud structure to a flux rope model. We will use Wind plasma and IMF data on counterstreaming particle events, He enhancements, event composition, and shocks to compare with CME source structures at the Sun to better understand how to forecast Earth arrival of geoeffective events. A focus will be on how reliably the direction and strength of the IMF southward component, and the sign of the helicity of the field can be predicted from the solar and interplanetary data sets. Both the PI and Co-I have collaborated in studies of a few events involving apparent flux ropes arising from solar filament and arcade eruptions and how the sun sheds magnetic flux and helicity. The proposed effort is a logical extension of that work to a larger data set allowing us to test present assumptions about predicting space weather, and to greatly enhance our knowledge of the magnetic structure of CMEs. Our proposed program is relevant to NASA's SEC Theme and the LSW program and the techniques pertinent to future NASA space missions such as SMEI, STEREO, Solar Polar and Solar Dynamics Observatory.

Wing, Simon / Applied Physics Laboratory
Preparing for Multi-spacecraft Missions: Auroral Space-Time Scales and Magnetotail Assimilation Model

The roadmap of NASA SEC STP calls for launch of several multispacecraft missions, namely Magnetospheric Multiscale (MMS), Magnetospheric Constellation (MC), and Geospace Electrodynamic Connections (GEC). NASA SEC LWS program will also launch complementary multispacecraft missions, e.g., Ionospheric Mappers (IM). Our proposed work will help these missions in 2 areas: (1) develop a method to assimilate unprecedented multi-point data sets in unified and coherent manners, and (2) determine the optimal spacecraft orbit and spacing. These objectives will contribute significantly to the LWS program goals of (1) establishing a space weather research network and (2) developing cost-effective techniques for assimilating data from networks of spacecraft. These studies are described below.
1. We will exploit coincidences between FAST and one or more DMSP satellites to study (1) Large-scale electron acceleration events on the nightside and (2) Morning sector diffuse aurora. The particular focus of the study is space-time scales of energy transfer (in the form of particle precipitation) from the magnetosphre to ionosphere and thermosphere

in the auroral zone, which affects the conductivity, Joule heating, and the electrodynamics, including horizontal and perpendicular currents. From this study, we will be able to recommend the optimal/maximum/minimum IM spacecraft spacing and orbit for measuring auroral particle precipitation.
2. We will develop a magnetotail assimilation model which assimilates multi-point magnetospheric and ionospheric observations into a globally coherent and unified images of the magnetotail (tailward of ~8-10 Re). This model will be based on our recently developed technique which integrates ionospheric observations to create 2-D/3-D global images of the plasma sheet ion pressure, temperature, and density. We will verify and refine our technique with mid-altitude (Polar) and high-altitude (Geotail) observations. LWS currently does not plan any mission to the magnetotail, but our proposed method will be able to construct magnetotail plasma images with observations from IM along with MC, MMS, and GEC.

Winglee, Robert M. / University of Washington
Modeling ionospheric outflow in geophysically relevant coordinate systems

The outflow of ions provides an important coupling and transfer of mass and momentum between the auroral ionospheres and the outer magnetosphere. The transport of energized ionospheric ions to the tail requires hours, and allows for the possibility of long-term feedback effects between the magnetosphere and ionosphere. Such effects are interesting and perhaps crucial to understanding the development of substorms. The main obstacle is the fact that measurements of outflow (from low-altitude spacecraft) are performed relative to coordinate systems, which are only loosely related to the instantaneous configuration of the magnetosphere, e.g. MLT and ILAT. By contrast, one could imagine measuring the location and magnitude of ion outflows with respect to the instantaneous locations and strengths of field-aligned current systems. Such an ordering would allow outflow measurements to be used directly as either a ``boundary condition'' input for models or as ``ground truth'' for those capable of computing outflow.
We propose the adaptation of an existing, automated FAC-finding algorithm (developed for the FAST spacecraft) to the purpose of providing instantaneous, globally relevant coordinates, particularly with respect to the field-aligned current system, for observations of ion outflows onboard the Polar spacecraft. These observations will be crucial to differentiating ion outflow signatures during the development of substorms and storms, and will be able to differentiate changes in the outflows driven by periods of sustained southward IMF versus periods of predominant dawn/dusk IMF. Such dependencies cannot be derived by the present statistical studies that use MLT and ILAT only. The work will make an additional advance in that it will be used to provide crucial boundary conditions to global multi-fluid modeling that will then map the observed flows out into the magnetosphere. These global models will then be able to quantitatively determine their importance relative to that of the solar wind in the mass loading of critical regions of the magnetosphere, including the ring current, plasma sheet, and low latitude boundary layer.

Yung, Yuk Ling / California Institute of Technology

A Mechanism for Solar Forcing of Climate: Did the Maunder Minimum Cause the Little Ice Age?

Although there is circumstantial evidence that solar variability is implicated in climate change, no credible mechanism has been established. The main difficulty in establishing a mechanism is that changes in total solar radiation absorbed at the surface are too small to explain observed changes in climate. We will investigate a mechanism that amplifies the influence of the sun through UV-induced ozone changes in the stratosphere. We will test our hypothesis by investigating the effects of the Maunder Minimum in the 17th century, a time during which lower solar activity coincided with a cold spell known as the Little Ice Age.

We will improve upon our knowledge on the state of UV fluxes during the Maunder Minimum. We expect to show that a substantially decreased solar UV output (~10%) lessened the heating of the Earth's stratosphere during the Maunder Minimum through decreased absorption by ozone and oxygen. We will predict the response of ozone in the stratosphere using the Caltech/JPL 2-D photochemical model that includes the effects of catalytic chemistry and solar and cosmic energetic particles. The changes in stratospheric ozone would be used as input to the UCLA AGCM to drive major changes in heating rates and the stratospheric zonal wind patterns, which would in turn affect the propagation characteristics of planetary-scale waves. Since planetary-scale waves exist mostly in the troposphere, the change in stratospheric winds can indirectly affect tropospheric climate. We will analyze the state of the climate during the Maunder Minimum using the most recently obtained paleoclimate data and compare the model-predicted impacts with these data.

Our proposed mechanism couples the changes in solar UV emission to those of ozone and ultimately energy transport and circulation of the troposphere. If we successfully demonstrate that this mechanism is at work in the most modern climate models, this study will open a door to future space-borne observations of the solar-climate relationship.