Living With A Star Program: Abstracts of awarded proposals.
(NRA-01-OSS-01)

Below are the abstracts of proposals awarded funding for the Geospace Living With A Star Program. Principal Investigator (PI) name, institution, and proposal title are also included.

The Solar/Helio abstracts are shown at the end of this list.

Akmaev, Rashid A. / University of Colorado, Boulder

Solar Activity and Long-term Trends in the Ionosphere (SALTI): A Historic-data Analysis and Modeling Study

We propose a data analysis and modeling study of long-term changes that have occurred in the ionosphere and upper atmosphere over the last several decades. The interest in these trends has intensified after the classical modeling study by Rishbeth and Roble (1992) predicted quite dramatic changes in the thermosphere and ionosphere due to future increases in greenhouse gases. For the F2 ionospheric layer in particular, a substantial decrease of its height, hmF2, was predicted along with marginal changes in the critical frequency, foF2. The global ionospheric database consists of observations collected at nearly 200 ionosonde stations around the world over several decades. Previous analyses of the long-term changes in the ionospheric parameters have been inconclusive and even contradictory. The trend estimates cannot always be explained in terms of the model predictions possibly due to the difficulties of trend detection from the highly variable ionospheric data and due to the limitations of conventional proxies for the external drivers. Another possible explanation is the very strong influence on the ionosphere of solar and geomagnetic activity (the latter being also driven by the Sun), which in addition to cyclic and ÒrandomÓ variations exhibit considerable secular trends. The science goal of this project is to advance our understanding of the mechanisms driving the long-term changes observed in the ionosphere and upper atmosphere. Our approach is unique in that it synergistically combines two critical components: (1) we will conduct a comprehensive and robust statistical analysis of the global ionospheric database to delineate the contributions due to solar and geomagnetic activity, and detect possible anthropogenic and natural long-term trends; (2) we will use a suite of advanced upper-atmospheric and ionospheric models to study the natural and anthropogenic variability using the records of greenhouse gas concentrations, geomagnetic activity, and our improved historic reconstruction of the solar ultraviolet (UV) and extreme UV radiation over the last 2Ð3 solar cycles. A critical comparison of the results of data analysis and theoretical modeling will provide insights into the key physical processes responsible for the observed changes in the ionosphere and upper atmosphere and will lead to development of true long-term forecasting capabilities.

Barakat, Abdallah R. / Utah State University
I-M Coupling Along Auroral Field Lines: Mass and Energy Exchange Between Hot Magnetospheric and Cold Ionospheric Plasmas

Quantifying the behavior of the coupled ionosphere-magnetosphere (I-M) system is essential to developing the physics-based models of the solar-geospace connection. The mass/momentum/energy exchange between the ionosphere and the magnetosphere, and the particle energization in the auroral region, are critical to the onset and evolution of storms and to energetic particle distributions. When the cold, dense ionospheric plasma interacts with sufficiently warm magnetospheric plasma along the auroral field lines, a double layer forms across which exists a large parallel potential drop. This potential drop accelerates ionospheric ions, which in turn cause ion-beam-driven instabilities. The resulting wave-particle interactions (WPI) further heat the plasma, and hence, influence the behavior of the double layer. Understanding the coupling between these microscale and macroscale processes is crucial in quantifying the I-M coupling involving the hot-cold plasmas interactions. We propose to develop a model for the interacting hot-cold plasma transport along auroral field lines with a sufficiently high resolution in order to handle microscopic processes. This objective will be achieved using existing models previously developed at USU and UAH. The combination of the models will self-consistently synthesize the processes discussed above (double layers, WPI, Éetc.). Our macroscopic model includes all essential features of ionosphere physics such as collisions, chemical reactions, gravity, magnetic mirroring, centrifugal acceleration, WPI, temperature anisotropy, multi-ion and multi-electron populations including secondary, and scattered primary electrons. The main objective of our research will be to quantitatively determine the energy exchange between the magnetospheric hot and ionospheric cold plasmas via double layer formation and other associated processes. This study aims at resolving several outstanding questions such as: (1) how the energy is distributed among the waves, particles, and the double layer? (2) what processes control the formation, strength, and evolution of the double layers? (3) how does the ion heating efficiency depend on altitude, ion species, and physical conditions? (4) what factors control the flux and energy of the ionospheric plasma that escapes into the magnetosphere?

Christon, Stephen P. / Focused Analysis and Research
Energetic Ion Onset Fronts: Spatial/Temporal Variations In and Near Earth's Magnetosphere

The ISTP spacecraft constellation permits unprecedented detailed and multipoint examination of Solar Energetic Particles (SEPs) resulting from the large number of solar particle events produced in the recent Solar Cycle maximum as they approach and interact with Earth's magnetosphere. Abrupt SEP onset fronts can be used to test current understanding of interplanetary ion and electron propagation because they are initiated in localized solar events and have a simple transport history. Some SEP ions enter the magnetosphere and interact with communcation satellites, interrupt communications, and/or disable those spacecraft. Other SEP ions precipitate in polar regions, ionize neutral atoms causing aurorae and ion outflow, and, at high flux levels, contribute to surface communication disruptions. We propose a multicase/multpoint study of ~0.4-45 MeV SEPs using instruments on the ACE (at L1 ~230 Earth radii, Re) and nearer-Earth (~6.6-44 Re) Geotail, IMP-8, and GOES spacecraft, to examine spatial/temporal variability of SEP ion onsets observed near Earth since 1997 (ACE launch). The study organizes into Tasks to: evaluate the spaceweather monitoring effectiveness of a single spacecraft at L1; test whether the more abundant energetic ~0.4-5 MeV SEP ions have similar access to the inner magnetosphere (<=6.6 Re) as tens of MeV SEP ions; determine how often either nonuniform field-aligned particle streaming or assumption of an expanding spherically symmetric uniform onset front convecting with the solar wind is supported by observations; establish the range of flux level variability at SEP onset fronts; and compile/post a public list of SEP onsets from the four spacecraft. This study's results will: improve understanding of spatial/temporal variability of SEP onsets near Earth; enhance understanding of geospace interaction with SEP particles; supplement ongoing LWS studies of MeV-energy SEP ions; and be helpful in defining future LWS spacecraft mission constraints. Data Sets: -- GOES, Geotail, IMP-8, ACE

Clauer, C. Robert / University of Michigan
Temporal and Spatial Development of the Ring Current: Model Improvements and Validation Analysis

Geomagnetic storms are one of the most important phenomena with potential space weather consequences for human systems deployed in space and on the ground. The primary feature of geomagnetic storms is the growth of the ring current around the Earth. It is now widely recognized that the ring current development is asymmetric, with greatest intensity in the night side and dusk local time sectors. In general, the ring current does not become symmetric until late in the recovery phase. Thus, it is important to take into account both the temporal and spatial development characteristics of the ring current in models and analysis of the ring current. We propose to do this using a chain of over 20 mid-latitude ground magnetic stations to create maps of the temporal and spatial development of the storm time magnetic disturbance field. These will be compared directly with the magnetic disturbance produced by the Michigan RAM model of the ring current obtained using a Biot Savart integration. Major improvements to the model are proposed, which will include using a realistic electric field for the inner magnetosphere plasma transport in the RAM model obtained from data inversion techniques (AMIE inversion of high latitude ground magnetic data). In addition, the closure of the partial ring current via field-aligned currents will be investigated. The model, which is driven by upstream solar wind measurements and geostationary orbit plasma measurements, will be utilized to research the geoeffectiveness of solar wind drivers and the processes that affect the build-up and decay of the ring current. Validation of the global model will be through comparison with the ground-based magnetic disturbance maps and satellite (in situ and IMAGE) measurements.

Eccles, J. Vincent / Space Environment Corporation
Investigation and Development of Data-Driven D-Region Model for HF Systems Impacts

Space Environment Corporation (SEC) proposes a 3-year program to develop and validate a weather-capable D-Region model that assimilates solar & earth-space observations to provide a High Frequency (HF) absorption model for HF communication links and radar facilities. Motivation for the study is based on the low accuracy rates of climatological models in assessing the real-time impacts of solar and magnetic storms on HF communication systems. The proposed effort will include (1) optimization of D region model for fast, accurate absorption calculations, (2) develop assimilation algorithms for NASA satellite data streams for D-region/HF absorption model, (3) establish a low-cost HF-link monitoring and analysis effort for algorithm validation, (4) incorporate HF-link observations in assimilative model for regional improvements. The weather-capable D-Region/HF absorption model will account for solar induced impacts on HF absorption, including X-rays, Solar Proton Events (SPE's), and auroral precipitation variability. Ionosphere variability is induced by short time variations of solar electromagnetic radiation, energetic solar protons, solar wind and interplanetary magnetic field. The ionospheric variability greatly influences HF propagation characteristics and, thus, HF technologies. There are 20+ HF propagation and absorption programs developed in the last 30 years. These are based on climatological models of the ionosphere and are best used to aid in design of HF facilities. Currently, climatological models are being used in near real-time support of communications and radar communities. A growing base of evidence indicates that ionosphere climatology cannot provide suitable real-time support for the HF users. Data assimilating ionosphere weather models are being developed, but these models contain only E and F region altitudes. The D-region specifications are needed to correctly determine HF signal degradation. SEC proposes to undertake a program of algorithm development to assimilate space-based data from several satellites into an optimized D-region model. The data from WIND, IMAGE, POLAR, DMSP that relates to the ionization characteristics of the D region will be used to produce a weather-capable D-region model for use in HF propagation program.. Validation of the assimilation algorithms and model will be done using a large existing database of HF-links (PENEX) and a low-cost monitoring of an International HF Beacon network.

El-Alaoui, Mostafa / University of California, Los Angeles

Magnetospheric Current System During Disturbed Times

In this proposal we present a research program that will help provide a basis for the construction of a viable space weather model in the Living With the Star era. Such a model must provide both timely and reliable predictions of magnetospheric storms and substorms. The advance warning of solar disturbances given by solar wind monitors must be coupled to an accurate model of the magnetosphere, in particular the near-Earth region. Because the near-Earth region is the location of most spacecraft as well as vulnerable Earth based human technology, the prediction of conditions in this region is the primary goal of space weather research. The storm time injection of energetic particles into the ring current has a major impact on the near-Earth space. The physical models developed as part of the Living With a Star program must be capable of predicting the properties of the inner magnetospheric region with a high level of detail and specificity. Presently, global magnetohydrodynamic (MHD) are the most advanced models capable of simulating the entire magnetosphere and its interaction with the solar wind. Global MHD models have progressed in the last few years by using upstream solar wind observations to drive the simulations. These models however have limitations, particularly in their ability to model the inner magnetosphere. Our research program will significantly enhance the capabilities and physical realism of our global MHD simulation code and our model of the ring current through a systematic program that will result in a unified model. Time-dependent electric and magnetic fields obtained from a global MHD simulation will be used to carry out bounce-averaged particle drift calculations. A major element of our study is to use the parallel and perpendicular components of the particle pressure to feed back into the MHD momentum equation. We will validate our MHD and particle drift calculations by modeling both quiet and storm intervals. By iterating between measurements and theoretical calculations we will obtain a reliable set of MHD and particle drift models capable of accurately predicting the properties of the inner magnetosphere for a wide range of solar wind conditions. A global model that combines the magnetohydrodynamic approach with an inner magnetospheric model based on a bounce average drift model will be a major advance in the sophistication of the tools available to study the solar wind-magnetosphere-ionosphere system.

Farrugia, Charles / University of New Hampshire
Solar wind-magnetosphere-ionosphere coupling: Observations during magnetic conjunctions of Cluster with Svalbard

We propose to investigate the coupling of the magnetosphere to the ionosphere (M-I coupling) using observations made during magnetic conjunctions of the Cluster 2 suite of spacecraft with the ground optical site at Svalbard, Norway. Key regions included in these conjunctions are the dayside cusps, the low latitude boundary layer (LLBL), and the near-Earth nightside magnetosphere. With the dayside conjunctions we investigate the signatures in the optical aurora and ionospheric convection resulting from solar wind-magnetosphere interactions at the magnetopause and the LLBL. With the nightside conjunctions we seek to establish links between intensifications of the equatorward branch of the aurora during substorms, related local perturbations in the magnetic field and ionospheric flows, and injections of energetic electrons at the inner edge of the plasma sheet, thereby also furnishing constraints on models. The regulation of M-I coupling by interplanetary parameters is a major thrust of this work. For this investigation we shall employ (1) ACE interplanetary data; (2) the plasma parameters provided by the CIS instrument on Cluster 2; (3) ground-based meridian scanning optical photometers and all-sky imagers; (4) the particle and magnetic field measurements on Polar/HYDRA and MFE, respectively; (5) incoherent and coherent scatter radars; and (6) ground magnetometers. The proposed investigation builds on studies made from this ground site of the dynamics of the optical aurora as a function of interplanetary parameters, and on investigations of magnetosphere-ionosphere coupling during magnetic conjunctions with the Polar spacecraft and the ground optical site.

Goldhagen, Paul / US Dept of Energy Environmental Measurements Lab
Development and Validation of a Solar-Modulated Atmospheric Ionizing Radiation Model

This proposal addresses a prerequisite for modeling the effects of cosmic radiation on integrated circuits in aviation electronics, which are an increasing concern for avionics reliability. Before these effects can be accurately modeled for avionics under flight conditions, the incident fluence and energy distribution of each of the particle types that cause them must be known. Neutrons are the dominant particles causing effects on avionics components, but protons and light nuclei are also significant, and for high altitude flight platforms, high charge and energy (HZE) ions, which are notorious for causing single event effects. The nucleons and nuclear fragments are produced along with every other type of ionizing radiation in cascades of nuclear collisions initiated by primary cosmic rays striking atoms in the upper atmosphere. The fluence and energy distribution of the particles in the resulting atmospheric ionizing radiation (AIR) depend on altitude (atmospheric depth), geomagnetic location, and solar activity. Changes in solar activity cause galactic cosmic ray induced AIR particle fluence rates to vary by up to a factor of two or more. The proposed project will provide a detailed measurement-validated model of AIR for all locations in Earth's atmosphere and all solar activities. The new AIR model will be based on calculations of cosmic radiation propagation through Earth's atmosphere using the FLUKA and HEAVY Monte Carlo radiation transport codes. HEAVY transports helium and other ions as nuclei instead of as independent nucleons, enabling calculation of light-ion spectra and improving the accuracy of all the calculated particle spectra. Solar-activity dependent primary cosmic ray spectra for input to the transport calculations will be determined from fits to available data from space and balloon-borne measurements. The model will be validated using data from the NASA-funded AIR Project and other existing measurements. The AIR Project was an international collaboration of 15 laboratories that made simultaneous radiation measurements with 14 different instruments on several flights of a NASA ER-2 high-altitude aircraft. The primary instrument was a sensitive full-energy-range neutron spectrometer. The proposed Principal Investigator was the PI of the AIR Project. The new AIR model will enable improved calculations of radiation doses to air crews as well as accurate modeling of the effects of cosmic radiation on avionics.

Goodrich, Charles C. / University of Maryland
Integrated Numerical Simulation of the Solar-Terrestrial Environment for the Living with a Star Program

We propose to develop a general purpose software framework capable of linking the diverse simulation codes needed to model the solar-terrestrial environment from the base of the solar corona to the atmosphere of the earth. We will test and prototype use of this framework with a complete set of the leading codes in solar-terrestrial research through simulation of several data driven events. Such a computational infrastructure, in concert with new observational platforms and instruments, will be essential for the success of the Living with a Star program A joint team of simulation modelers and computer scientists with experience in large-scale code coupling will work together on this project. This is a major undertaking that will produce major advances. The benefits to the LWS program will include: Development and testing of a robust software framework capable of linking the simulation codes selected for LWS Integrated simulations from the corona to the upper atmosphere for several CME/magnetic storms and other geoeffective events. Understanding of the observations needed to run and validate the integrated codes Understanding of the data system requirements to supply input to the codes and store their output

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Hudson, Mary K. / Dartmouth College
A study of geomagnetic storms using global MHD and kentic radiation belt simulations

The goal of this project is to conduct a parametric study of various solar wind drivers of geomagnetic activity in order to understand their effects on the magnetosphere - ionosphere system, including the radiation belts. The polarity of the magnetic field orientation of magnetic clouds appears to be ordered by solar cycle and may have a determining role on geoeffectiveness when it impacts the magnetosphere. Furthermore, magnetic clouds are often accompanied by interplanetary shocks, high speed streams, and trailing density enhancements. The development of an understanding of the fundamental physics involved in these interactions is an explicit goal of this proposal. This effort is an outgrowth of two projects that have been undertaken to successfully model geomagnetic storms. The Lyon-Fedder-Mobarry (LFM) global MHD code has been used to simulate the magnetosphere under a variety of solar wind conditions including the January 10-11, 1997 Magnetic Cloud event. A 2D relativistic guiding center test particle code has been developed which can use the equatorial electric and magnetic fields from the LFM as input to model the evolution of the radiation belts. It has been used to model the electron energization and transport during the January 10-11 event, the radial transport and trapping of solar energetic protons to form a new proton belt during the March 24, 1991 storm, and eight other storms simulated approaching the current solar maximum. In the three year proposed project we will conduct a series of MHD simulations using both L1-measured solar wind conditions and idealized parameters to test model sensitivity to different solar wind conditions. The study will focus on 1) varying the polarity of magnetic clouds, 2) varying the speed of an ICME shock and 3) high speed solar wind conditions in the absence of an ICME. The differences between configurations will be quantified by using proxies from the ionospheric energy deposition, D_{st}, and AE. In addition, the effects of these configurations on the radiation belts will be compared with observations from the Polar, SAMPEX and HEO spacecraft by using the results of the guiding center test particle code. The project, under the direction of Dr. Mary K. Hudson, will utilize the significant expertise of the Space Plasma group at Dartmouth College, including Dr. John Lyon, Dr. Michael Wiltberger, as well as graduate students.

Huston, Stuart L. / Boeing Phantom Works
Long-Term Dynamics of the Trapped Radiation Slot Region

We propose to conduct a study of the long-term behavior of the slot region of the Earth's trapped radiation belts using data primarily from the NOAA POES spacecraft. This effort will cover over two solar cycles worth of data, and will concentrate primarily on the frequency and intensity of transient radiation belts such as the one observed in March 1991. The study will also develop a statistical description of the energetic proton flux levels experienced in the region $2 < L < 4$ over time. This study will contribute to LWS science goals by providing a statistical description of the climatology of the slot region, as well as a long-term data base on which theoretical studies of the acceleration and transport of charged particles within the magnetosphere can draw.

Kauffman, Billy / Space Environments and Effects (SEE) Program
Variability in the Low Earth Orbit Plasma Environment

The goal of the study is to improve scientific knowledge of plasma environment variability in low Earth orbit (LEO) over a solar cycle and develop models of the variability that enable cost-effective design of spacecraft and subsystems. The models will aid the spacecraft designer in minimizing damage and effects of the space plasma environment on their systems by providing ready access to statistical estimates of variations in plasma number density and temperatures from mean values. This information is required for use in spacecraft charging calculations and other plasma effects on spacecraft for quantitative estimates of space environment impact. The proposed work will analyze the LEO plasma environment using historical data sets of plasma number density and temperature available from a variety of sensors onboard spacecraft to produce environment definitions that can be used in spacecraft charging, sputtering, and other plasma analysis. A range of altitudes from 200 km to 2000 km is the primary goal, including the range of altitudes from 750 km through 900 km often used for polar orbit missions and the 350 km to 450 km range of altitudes planned for International Space Station (ISS) operations throughout the ISS mission lifetime. 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 Targeted Research and Technology Program.

Keskinen, Michael J. / Naval Research Laboratory
Towards a Predictive Model of Equatorial Ionospheric F-region Irregularities

The objective of the proposed research is to develop a model of the spatial and temporal structure of the plasma density irregularities in the equatorial and low latitude F-region ionosphere for a range of geophysical conditions. The focus will be on ionospheric irregularities that can lead to disruptive effects on communications, navigation, and radar systems. The approach will be to study the nonlinear evolution of the Rayleigh-Taylor instability in the equatorial ionosphere for a range of conditions. The effects of pre-reversal vertical drifts, neutral wind effects, background Pedersen conductivity effects, and magnetic storm conditions will be studied. A predictive model of equatorial spread-F irregularities will be developed.

Lummerzheim, Dirk / University of Alaska, Fairbanks
Large-scale consequences of small scale auroral structures (LWS)

Small-scale processes in aurora have impact on the large-scale behavior of the ionosphere-thermosphere system, and the coupling of the magnetosphere-ionosphere system. Current large-scale and global models do not include sufficient resolution and detail to treat the small-scale physics of M-I coupling. The missing small-scale terms lead to inconsistencies between models and measurements. Using measurements of the ionospheric electric fields, currents, and conductivities with global data assimilation and modeling to derive thermospheric heating sources and temperatures does not agree with observations. The mismatch of the needed and calculated heating sources can be as large a factor of two. With this proposal, we will characterize and quantify the heating sources that result from small-scale auroral structure using observations and modeling. We will derive a parameterization of the effects of the small-scale structure to be included in global models.

McIlwain, Carl E. / University of California, San Diego
Measurement of Electromagnetic Fields via Flight Times from Spread-Beam Electron Sources

We propose to develop and evaluate a new concept of electron-drift instrument that relies solely on time-of-flight measurements from multiple spread electron beams to extract measurements of ambient electromagnetic fields. We expect such an instrument to be applicable to many missions, but in particular to be ideally-targeted to the task of monitoring and/or mapping key parameters of geospace disturbances from spacebound platforms with high time resolution, low influence from spacecraft disturbances in the ambient environment, and low demands on spacecraft resources. We envision a two-phase process in the evolution of this new instrument. In this first phase, we will develop a design concept with reduced demands on both spacecraft resources and maturity of component technologies, to provide the basis of an instrument definition for future missions aligned with LWS objectives. We will define and evaluate key components of this design and will undertake a comprehensive examination of its capabilities and limitations for a number of conceivable mission configurations, objectives and environments. A future phase of development of this instrument (enabled by emerging higher-speed sensor technologies and modestly increased demands on spacecraft resources) will fulfill the promise of full-vector measurements of electromagnetic fields and gradients at even higher resolution in time, magnitude and direction.

Papitashvili, Vladimir O. / University of Michigan
Storm-time and solar cycle effects in the high-latitude magnetosphere-ionosphere coupling

Solar activity determines a global impact on a multi-scale, coupled system of geospace environment through the interaction of the solar wind (SW) plasma flow and interplanetary magnetic field (IMF) with the EarthÕs magnetosphere. Existing abundance of various satellite observations obtained over last two decades motivates us to investigate if there are any significant effects in the solar wind-magnetosphere-ionosphere coupling regime with a course of the solar activity cycles. We will focus on the dynamics of the "quiet" and "storm-time" auroral oval and the corresponding changes in the global ionospheric plasma convection and field-aligned current distributions. In this way, we will be able to investigate how the "quiet" and "storm-time" magnetosphere-ionosphere coupling system evolves with the solar cycle. Thus, our overarching goal is to improve our knowledge of the role of solar influences in affecting the near-Earth space environment conditions. We propose to produce statistical patterns of the global high-latitude ionospheric convection, using ion drifts data from a series of DMSP satellites (1987-2001, 22-23 solar activity cycles), and the field-aligned currents distributions inferred from geomagnetic field measurements onboard the Magsat (1979-1980), ¯rsted (1999-2001), and a series of DMSP satellites (1987-2001). We will undertake this statistical study separately for the quasi-steady, average IMF/SW conditions, for the extremely quiet times, and for the magnetic storms. The obtained results will be compared with the auroral emissions from UVI images taken onboard of the NASAÕs POLAR spacecraft during 1996-2001 (solar cycle 23). Combining our studies of the statistical patterns and "case-by-case" events (specifically, magnetic storms and extremely quiet times), we will be able to separate effects of the "directly-driven" and "loading-unloading" processes (mainly responsible for the polar cap nd auroral zone disturbances, respectively) on the entire magnetosphere-ionosphere coupling system over the solar activity cycles. The resulting quantitative estimates can be utilized in various geospace circulation modeling efforts, including the global MHD models. The tools, resulting datasets, statistical models, and case studies will be made available for the scientific community via the SPRL World Wide Web site http://www.sprl.umich.edu/mist/.

Psiaki, Mark / Cornell University
Dual Frequency GPS Software Receiver Development for Ionospheric Scintillation Measurement

Dual frequency software Global Positioning System (GPS) receivers will be developed to measure ionospheric scintillations. They are part of a GPS instrument that will be proposed for use on NASA's Ionospheric Mappers mission. Currently available GPS technology is inadequate for space-based scintillation monitoring, and the proposed receivers will fill this technology gap. The work will develop specialized signal processing algorithms for use in a dual frequency bit-grabber/software-receiver system. Such a system uses a minimal RF hardware front-end in conjunction with software that runs on a microprocessor. This set-up allows for after-the-fact processing of RF data. This mode of operation opens up the possibility of using non-causal signal processing algorithms. Such algorithms can enhance the gain of the tracking functions, which enables the receiver to detect and track weaker signals than can be tracked in a real-time receiver. The ability to track weak signals is critical when measuring ionospheric scintillations because they can cause deep fading of the received signal's power. This proposal will develop signal tracking algorithms that use non-linear smoothing techniques from the field of estimation along with FFT block-processing algorithms. They will be applied to track both of the GPS spread spectrum signals, the 1575.42 MHz

L1 signal and the 1227.6 MHz L2 signal. The receiver will measure the effects of ionospheric scintillations on the following quantities: the amplitude and phase of each carrier and the two frequencies' differential group delay and differential carrier phase advance. These quantities characterize the diffraction effects of the scintillations and their impact on the Total Electron Count in a 1m-by-1m column from the receiver to the tracked GPS satellite. These developments will support Sun-Earth-Connection studies of Geospace disturbances. The developed software receiver will be ideal for use as the GPS instrument on NASA's proposed Ionospheric Mappers mission. The ionospheric scintillation data that it will measure will improve our understanding of these disturbances and will help us to develop operational radio receivers that are better able to cope with these effects. This knowledge will translate into reduced operational problems for other NASA missions that rely on GPS information for navigation and attitude determination, missions such as the Space Shuttle and the International Space Station.

Raeder, Joachim / University of California, Los Angeles
Geospace Modeling with Adaptive Mesh Refinement

This project aims at the development of an efficient and versatile adaptive mesh refinement (AMR) code to solve the three-dimensional, time-dependent equations of ideal magnetohydrodynamics (MHD). This code will be based on the Structured Adaptive Mesh Refinement Applications Infrastructure (SAMRAI) developed at the Center for Applied Scientific Computing (CASC) of the Lawrence Livermore National Laboratory (LLNL). This project will implement a conservative integrator for Faraday's law along with with conservative integration schemes for the hydrodynamic equations, the coupling terms, and different boundary conditions. The code will be extensively tested, various flux-limiting algorithms will be evaluated in the context of AMR, mesh refinement strategies will be developed, and AMR specific data analysis and visualization tools will be developed. The ultimate goal is to allow for simulations with sufficiently high resolution in current sheets that numerical dissipation is suppressed to the point that magnetic reconnection ceases. This would constitute a quantum-leap in the simulation capabilities of solar, heliospheric, planetary, and astrophysical plasmas, which at present cannot be modeled without introducing reconnection due to numerical effects. Although the development is primarily targeted at magnetospheric simulations, including space weather applications, the codes will be made freely available and likely find applications in various fields that are concerned with the large-scale modeling of collisionless plasmas.

Richard, Robert L. / University of California, Los Angeles
The Importance of Solar Energetic Ions for the Magnetosphere

Solar energetic particles (SEPs) are electrons, protons, or heavy ions that are accelerated due to solar activity. Solar flares and interplanetary shocks associated with coronal mass ejections (CMEs) are the most important sources of these particles. SEP ions can be a major source of energetic particles for the EarthÕs magnetosphere. We know several ways energetic ions can reach magnetospheric field lines. To understand the entry of these ions into the magnetosphere and to model it more quantitatively we need more detailed calculations of SEP entry and transport in realistic models of the magnetosphere and its interaction with the solar wind. One approach to quantifying ion entry and identify its mechanisms is to follow a large number of test ions in magnetic and electric field models of the magnetosphere. We have used global magnetohydrodynamic (MHD) models of the magnetosphere to obtain the magnetospheric fields for particle tracing calculations. Test particles (protons, electrons or heavy ions) were launched upstream of the magnetosphere in the solar wind at energies between 0.1 and 50 MeV. We have performed calculations for idealized steady and slowly varying interplanetary magnetic field (IMF) conditions; that is, the IMF was held steady or changed over an interval of half an hour. Often, however, SEPs accompany interplanetary shocks that cause disturbed, rapidly varying magnetospheric conditions. The coupling of SEPs with a shocked magnetosphere can strongly enhance ion entry. The goal of this proposal is to understand and quantitatively model this enhanced ion entry process. We will perform MHD simulations of the magnetosphere in which it is struck by a shock. Then we will calculate the trajectories of test ions in these field models. The question we wish to address is how ions enter a shocked, rapidly varying magnetosphere, because under these conditions ions can penetrate the inner magnetosphere in large numbers. The entry process may not resemble that for steady and slowly varying IMF. We will evaluate transport into the magnetosphere, especially into the inner magnetosphere, and precipitation at the Earth. Energetic particle measurements by geosynchronous satellites will be used to evaluate the features seen in the model results, such as a strong increase in SEP transport into the inner magnetosphere in the shocked case.

Shue, Jih-Hong / Applied Physics Laboratory
A comprehensive study of relationships between solar wind density and auroral electrojets

It is well known that sudden pressure enhancements associated with the solar wind density compress the magnetosphere, increasing large-scale currents in the magnetosphere-ionosphere system. Relationships between the solar wind density and auroral electrojets are qualitatively known to be different for different interplanetary magnetic field (IMF) orientations. The relationships for southward IMF are much stronger than those for northward IMF. However, their quantitative relationships and responses of the magnetosphere-ionosphere system to the solar wind density variability have been less fully investigated. In this proposed study, we will first search for events with a density variation but for which other solar wind parameters are relatively constant using solar wind data from the Wind spacecraft. We will also calculate the changing rates of auroral electrojets (characterized by the AU and AL indices) per unit of the solar wind density for these events. We will then construct a database, which contains the changing rates and various solar wind parameters, and pursue a parameterization study. With this database we can determine that, under which solar wind conditions, the density effect on the auroral electrojets will be most significant. A clear articulation of such a significant effect should motivate theoretical focus. We will also derive a representation of the changing rates in terms of the IMF By, Bz, and solar wind velocity. In addition to the parameterization work, we will perform case studies using multiple observations (Polar UltraViolet Imager, Defense Meteorological Satellite Program particle precipitation, plasma flow, and magnetometer data, and Super Dual Auroral Radar Network convection data) by choosing events which have a large density variation. These case studies allow us to scientifically understand how the density variations affect the electrodynamic properties of the magnetosphere-ionosphere system, including auroral electrojets, auroral brightness, ionospheric convection, particle precipitation, and field-aligned currents. These case studies also allow us to investigate the relative importance of the conductance and the electric fields to the auroral electrojets during the density variations.

Takahashi, Kazue / Applied Physics Laboratory
Modeling geospace plasma mass density based on the frequency of ULF waves

Plasma mass density is one of the fundamental quantities characterizing the plasma in the geospace. The density is related to a number of space weather issues including satellite drag, generation of killer electrons, ion escape to the solar wind, and long-term changes in the solar irradiance. Despite the importance of the mass density, this quantity is often poorly determined from in-situ measurements. In the proposed project we will construct a mass density model using the frequency of standing Alfven waves excited in the magnetosphere. We will determine the frequency using magnetic field measurements from geostationary and other satellites spanning more than a solar cycle. The density corresponding to the observed frequency will be obtained by numerically calculating the standing wave frequency using a realistic magnetic field and a density distribution along the field line that can be adjusted to fit the observation. A density model will be constructed statistically as a function of local time and radial distance and including dependence on the geomantic activity and solar cycle. It is important to carry out the project in the context of the NASA Living With a Star (LWS) program. As mentioned above, there are several reasons for having an improved magnetospheric mass density model in relation to spacecraft operations and human activity on and off the Earth.

Toffoletto, Frank R. / Rice University
Initial development of an analysis model of the Inner Magnetosphere

We propose to develop an analysis model of magnetospheric space weather based on statistical information from previous missions, optimal interpolation techniques, and basic physics. The model will be designed as a tool to make optimal use of data from the Living with a Star Geospace Mission. Analysis models are used extensively in the meteorological community to produce weather charts and frontal maps. Similarly, a principal goal of our proposed analysis model will be production of magnetospheric weather charts for use during the Living with a Star Geospace Mission, making optimal use of available data to specify the state of the magnetosphere. Initially, we plan to focus on three important aspects of space weather: the magnetic field, fluxes of radiation-belt particles, and fluxes of kilovolt electrons. Our analysis model will include four elements: a background empirical model, available observational data, a model error covariance matrix, and a physics checker/corrector. The methodology is based on a variant of least-square estimation theory. We will produce a set of background model outputs for different model inputs. From these results we will develop an error covariance matrix for the outputs of interest. Using the error covariance matrix, we will construct a space weather chart by adjusting the background model to optimize agreement with global observations, consistent with the inherent correlations of the empirical model. In order to ensure a physically meaningful solution, we will pass the results of the maximum-likelihood estimate through a physics checker/corrector. This routine will force the resulting space weather map to agree with well known and well understood physical laws (like div B =0 or nion ? nelectron). Our initial tests will be Observation System Simulation Experiments (OSSE), which use artificial data made up of select points from the input model and noise. By evaluating the value added to the space weather map by including data from an array of hypothetical orbits, the analysis model will be able to provide assistance in orbit determination for future missions. After our initial OSSE, we will test and tune the analysis model with historical data from CRRES and other missions. In this way, the model will be ready for use as soon as the Living with a Star Geospace Mission and other new data sources become available.

Vassiliadis, Dimitris / USRA Universities Space Research Assoc
Dynamics of energetic electron fluxes in the inner magnetosphere

This is a proposal for an energetic electron model and its coupling to solar wind parameters, primarily the radial speed, the solar wind density, and the interplanetary magnetic field Bz. The community needs such a model and observations and modeling have reached an appropriate completeness level to address this need. We will develop a set of models a range of L shells coupling them to each other and the solar wind variables. The model will be fit to SAMPEX/PET data and its coefficients will provide the timescales of the interaction, the main regions in L shell, and the seasonal variation. The input to the model will be solar wind key parameters from a solar wind monitor such as those provided currently by ACE. Validation of the model will be done with out-of-sample SAMPEX data and, at geosynchronous orbit, with Los Alamos spacecraft data. A database will be made available for wider use and further model development by the research community.

Below are the abstracts of proposals awarded funding for the Solar/Helio Living With A Star Program. Principal Investigator (PI) name, institution, and proposal title are also included.

Bailey, Scott M. / University of Alaska, Fairbanks
The Magnitude and Variability of the Solar Soft X-ray Irradiance

The overall goal of the proposed effort is to determine the magnitude and variability of the solar soft X-ray irradiance; in particular, we wish to understand how the solar soft X-ray irradiance varies during the approach to and during solar maximum conditions. This will be accomplished through analysis of existing data from the Student Nitric Oxide Explorer (SNOE) satellite. While the SNOE mission has produced significant advances in our understanding of the solar soft X-ray irradiance, important questions remain. We seek to answer the following questions: 1. What is the magnitude of the solar soft X-ray irradiance during solar maximum conditions? 2. How does the 27-day variability of the solar soft X-ray irradiance during solar maximum conditions compare to the 27-day variability during moderate and solar minimum conditions? 3. How does the solar soft X-ray irradiance relate to commonly available proxies such as F10.7 and He II core-to-wing ratios during solar maximum conditions? Are linear relationships derived from moderate solar activity observations valid at high solar activity?

Baldwin, Mark P. / NorthWest Research Associates, Inc.
Role of the stratosphere in amplifying the 11-year solar cycle

Research during the past several years suggests that there is a discernable influence of 11-year solar variability on the atmosphere, in particular the stratosphere. There is also strong observational and modeling evidence that low-latitude stratospheric circulation anomalies are communicated poleward and downward through a dynamical mechanism involving planetary-scale waves. This process amplifies circulation anomalies and draw them downward as far as the Earth's surface, where they affect weather and climate. The proposed investigation will relate solar cycle effects in the tropical stratosphere to extratropical anomalies, and the amplification of these anomalies as they progress downward through the atmosphere. We propose to: 1. Use a variety of observational data sources to study tropical wind variability in the stratosphere. This region appears to be crucial not only for direct solar effects but for the communication of a solar signal to the extratropics. 2. Examine the development, in latitude, height, and time, of equatorial stratospheric circulation anomalies related to solar variability. We will use annular mode indices as a tool to examine hemispheric variability related to the solar cycle. 3. Use a primitive equation model spanning the troposphere, stratosphere, and mesosphere to probe the observational findings, and to examine the effects of changes to and timing of equatorial stratospheric wind anomalies. The proposed study represents an important component of NASA's Living With a Star Program, which is focused on an increased scientific understanding of the Sun-Earth system as it affects weather, climate, and society. In addition, we will use data from current and past NASA missions. The proposed study is relevant to the Living With a Star Program for three reasons: 1. The focus is on the dynamical role of the stratosphere, how stratospheric processes are sensitive to solar forcing, and how wave-induced momentum transport can amplify solar signals, drawing these signals poleward and downward. 2. The proposed effort involves a combination of data analysis and numerical modeling, with a goal of improving our understanding of how solar variability is linked to surface weather and climate, which affects life and society. 3. An improved understanding of these processes should enable us to better separate natural solar variability of the climate system from anthropogenic trends.

Berdichevsky, Daniel / Emergent Information Technologies - East
Connecting Shock Parameters to the Radiation Hazard from Energetic Particles

The highest intensities of energetic particles have been observed at interplanetary shock passage. These produce the greatest radiation hazard to astronauts. We focus on shocks driven by ejected material from the Sun, which from the start of the ejection, are associated with particle acceleration, in some cases into GeV energy levels. The study of the relationship between particle acceleration and the spatial extent of the shock takes advantage of an available, extended coverage of Helios and IMP-8 of the solar cycle 21st, including the solar maximum interval near 1980 with many solar energetic events. First we identify the character of the shock by estimating the likely location of the monitor relative to the shock nose and comparing the shock strength at three wide by different locations in longitude. Second we take into consideration the presence or absence of its driver, and the intensity of the energetic particle seed population at the time of coronal mass ejection (CME). Shock measurements, then are organized by their spatial extent, proximity to the shock-nose, and identified presence of energetic particle seed population at the start of the event. For these categories we identify the relationship between energetic particle acceleration at the shock are the local shock speed and strength evaluated using shock parameters consistent with the thermodynamic Rankine-Hugoniot condition. For those shocks observed with Wind, GEOTAIL and IMP-8, and later also with ACE, we perform a correlation study of the local changes in the upstream solar wind conditions at the passage of the shock and their influence on the acceleration process of energetic particles. During the Wind era it is also possible to obtain an almost continuous coverage of the likely source of the solar transient (CME observations with LASCO/SOHO, and the tracking of the shock in the interplanetary medium with WIND/WAVES instrument.) The understanding we achieve from the proposed study will provide the space community with the skill to predict levels of radiation at shock passage when the initial radiation levels, shock front extension, and ejecta speed at Sun are measured remotely near the Sun. The proposed work addresses the need to improve our scientific knowledge of space environment conditions with a new, multi-spacecraft use of proved observational techniques.

Biesecker, Douglas Alan / Emergent Information Technologies, Inc.
Determining the properties of Earth-directed Coronal Mass Ejections

Early detection of coronal mass ejections (CME's) is now possible. However, the physical properties of a CME need to be known in order to predict the effects it will have on space weather. Recent work has shown that EUV/X-ray dimmings in the low corona and EIT waves are intimately related to CME's. In this proposal, we show how the origin of the mass, its distribution, and the dynamics of a CME are reflected in the associated dimming and wave. This investigation will use SOHO/EIT observations of EUV dimmings and EIT waves and SOHO/LASCO white light observations of CME's. By examining events observed in both telescopes, the radial, latitudinal, and longitudinal distribution of mass in CME's and their bulk velocity will be related to the EUV dimmings and waves. We expect to show clear relationships between the EUV data and the white light observations. Studying the CME, dimming, and wave together will help us to understand more about the physics of CME's. In addition, the results of this proposed work can be used to study and make predictions of the geoeffectiveness and arrival time of Earth directed CME's. Because these phenomena appear during the earliest stages of a CME, space weather predictions can be made in real-time.

Cohen, Christina M. S. / California Institute of Technology
Forecasting Shocks and Energetic Particle Hazards Using L1 Monitors

We propose to identify, characterize and model shock events and associated energetic storm particle (ESPs) events using available data from the ACE, Wind, and IMP 8 spacecraft. Where possible we will monitor the movement of the shocks through the

Earth*s magnetosheath using data from Geotail and Interball. This work will extend the understanding of shock acceleration and the propagation of these disturbances through the interplanetary medium and the magnetosheath and speaks to furthering our understanding of the effects solar activity has on the Earth's environment. We propose to use this knowledge to develop a radiation hazard warning system to be utilized by astronauts, NASA, and operators of various satellites. This warning system will rely the current Real-Time Solar Wind system which makes ACE plasma, magnetic field, and energetic particle data available to the public within 5 minutes of transmission. By developing automatic algorithms that will identify and classify shocks, ESPs and on-going solar energetic particle events, this warning system will produce estimates of the Earth arrival time of the shock and quantitative predictions/evaluations of the pending increase in radiation hazard with ~30-60 minutes of lead time. This will allow the appropriate precautions to be taken to limit human exposure to the increased radiation hazards and to protect sensitive equipment.

Connell, James J. / University of Chicago
Development and Testing of a New Angle Detecting Inclined Sensor (ADIS) System

The Living With a Star (LWS) program is directed towards better understanding the near-Earth environment. The proposed research has, as its main goal, an improved technology to build inexpensive, low-power, low-weight instruments that can measure the charged particle environment. We propose to proof-test a new system, an Angle Detecting Inclined Sensors (ADIS) System, which can determine the angle of incidence of charged particles in space based instruments. We propose to develop and test an ADIS system using solid state silicon detectors in order to show the feasibility and practicality of using such a system. ADIS could have applications in measurements of Solar energetic charged particles as well as anomalous component ions and Galactic cosmic rays. Our proposed system should be able to identify electrons and to separate charged particle isotopes from hydrogen through neon and elements through nickel. Systems presently used as position sensing detectors (PSD's), such as solid state strip detectors or optical fibers, require significant power to operate and often add weight to an instrument, either directly or through the added electronics. Passive systems, such as curved detectors, have relatively poor isotopic resolution and cannot make measurements at the lowest energies. Our ADIS system addresses these limitations. An ADIS system determines the angle of incidence of a charged particle based only upon energy deposits in detectors which are inclined with respect to each other. These same energy deposits are used as part of the dE/dx measurements used in a dE/dx vs E method of particle determination. Because a single set of measurements is used both for the determination of the angle of incidence and for the dE/dx measurement, no extra electronics are needed, so an instrument with an ADIS system can meet both weight and power constraints usually required in space instruments. Anisotropy measurements are also available since ADIS determines particle trajectories. The simplicity of the ADIS system should decrease the cost to build a space based charged particle instrument. It should be noted that a nearly identical proposal was submitted to the Solar and Heliospheric Science (A.2) program. The proposed research is fully appropriate to both programs.

Cook, John W. / Naval Research Laboratory
3D Reconstruction of White Light Coronagraph Images from Two Viewpoints

Proposal Objectives: We propose to systematically investigate the 3D electron density distribution reconstructions from white light coronagraph images, and their limitations, which are achievable from only two solar viewpoints in the ecliptic plane. The future STEREO mission, due for launch in 2005, will carry twin copies of the SECCHI experiment, each with three white light coronagraphs. The coronagraph reconstructions have the special difficulties of minimally determined solutions (only two viewpoints) and optically thin lines-of-sight. We employ a reconstruction technique using the PIXON algorithm, a mathematically sophisticated method whose execution time scales only as the number of voxels N, not as a power of N, and which should produce reconstructions from 1024x1024 CCD white light images in less than a day. Research plan: We will apply our reconstruction technique to synthetic data and to existing solar observations for scientific investigation of polar plumes, equatorial streamers, and CMEs. We will develop our 3D reconstruction technique to incorporate the geometry and physics of solar coronal observations from arbitrary vantage points; investigate initial reconstructions from simple geometrical volumes; use reconstructions of existing SOHO LASCO data to investigate geometry and hydrostatic equilibrium of polar plumes; use reconstructions of existing SOHO LASCO data to study the evolution of equatorial streamers, their relationship to active regions, and their comparison to extrapolated magnetic fields; and investigate the effects of noise, velocity, viewing angle (elongation), image contrast, and background models on the reconstructions of synthetic CMEs produced from MHD models. Relevance to NASA programs: STEREO is the first space mission of the Living With A Star program, and it is imperative that techniques for analysis of the STEREO observations, including those from the SECCHI coronagraphs, be developed before actual launch of the spacecraft. 3D reconstruction from coronagraph images supports the development of "new techniques and models for predicting solar/geospace disturbances," where it can be used to distinguish and model Earth-directed CMEs observed by future missions such as STEREO.

Dikpati, Mausumi / National Center for Atmospheric Research
Predicting the Strength of New Solar Cycles by Fitting Old-cycle Magnetic Field and Meridional Flow Data Into a Flux-transport Dynamo

Predicting the strength of a new solar cycle by using old cycle data has so far been attempted either by using an empirical "precursor method" or by a dynamo-based scheme with thin physical foundations (see the discussion and criticism in Joselyn et al. 1997, Eos, vol. 78, No. 20, p.205, 211-212). Such prediction may now be possible by using a flux-transport type solar cycle dynamo model. The cyclic evolution of the solar magnetic field on 11-year timescales is generally believed to be the consequence of an oscillatory dynamo, operating inside the Sun. Over the past six years, flux-transport-type kinematic, mean-field dynamos have been most successful in reproducing large-scale solar cycle features (Durney 1995, SolP, 160, 213; Choudhuri, Schuessler and Dikpati 1995, A&A, 303, L29; Dikpati and Charbonneau 1999, ApJ, 518, 508; Charbonneau and Dikpati 2000, ApJ, 543, 1027; Dikpati and Gilman 2001, ApJ, Sep 20 issue, in press). All these models show that the observed mean meridional circulation may determine the cycle-period. Fluctuations in this weak flow and in the poloidal field source-term can also reproduce the amplitude-duration anticorrelation and clock-setting properties of the observed solar cycle. We propose the following steps for future research aimed at predicting the strength of the new solar cycle: (i) develop a scheme to make the model operate with observational data, (ii) process the observational data for magnetic field and meridional circulation from the previous cycle (prior to 1996) to initialize the flux-transport dynamo model, and evolve the model, (iii) form suitable proxies for the model output to compare with observations, (iv) investigate whether this model can reproduce the known magnetic field strength and pattern in later years. As the project progresses, with further experience and knowledge gained, we plan to explore the effect of a back-reaction on the meridional circulation by generalizing the model to include such back-reactions. This process may lead to the first dynamo based prediction models for the solar cycle based on data like that from the SOHO MDI instrument or the proposed SDO Helioseismic and Magnetic Imager.

Fry, Craig D. / Exploration Physics International, Inc.
Living with a Star: Development of an Observation-Based, Hybrid 3D-MHD Model for Predicting Solar Wind Conditions During all phases of the 11-Year Solar Activity Cycle

a. Objectives: We propose to develop a hybrid kinematic/3D-MHD solar wind model to simulate realistic solar wind conditions over a range of solar activity levels. Our goal is to improve the scientific understanding of the propagation and evolution of solar disturbances, in order to ultimately predict their eoeffectiveness and impacts on human technologies. In this project, we will focus on modeling solar wind conditions using solar data as inputs. b. Methods and Techniques: We will develop a new observation-based solar wind model by combining a modified kinematic model of the inner heliosphere with a full 3-D magneto-hydrodynamic solar wind model. This new hybrid model will be driven by observations of ambient solar conditions and transient events, and applied to a number of scenarios of solar disturbances throughout the 11-year solar activity cycle. The modeling system will be used to characterize and predict solar wind conditions, including corotating interaction regions, interplanetary shocks and the IMF lines connecting the traveling shock region to the Earth and L1, within a non-uniform ambient solar wind. We

will apply our model to a list of candidate solar events having the potential for space weather impacts. We will study the evolution of the IMF at the interplanetary shock surface, with particular emphasis on the turning and recovery of Bz and its relationship to geomagnetic storms. Results will be interpreted by comparing modeled and observed solar wind speed, density, and IMF topology at the ACE and WIND spacecraft locations.
c. Significance: This proposal is unique because we will combine, for the first time, our observation-based kinematic modeling system with a full 3D-MHD solar wind model. This will enable new comparisons of solar wind predictions with spacecraft observations. This in turn will allow NASA to quantify the relative importance of various solar disturbance sources to the transfer of energy from the Sun to the terrestrial system. This modeling effort is relevant to HEDS as a critical step in the subsequent development of observational solar energetic particle propagation models for predicting particle fluxes and fluences at Earth, Mars, and Earth-Mars transit orbits.

Haggerty, Dennis / Applied Physics Laboratory
Solar energetic electrons as predictors of geo-effective CME-driven shocks and solar energetic particle events

We propose that near-relativistic (40-300 keV) solar electrons may be useful predictors of prompt solar energetic particle (SEP) events, as well as subsequent energetic storm particle (ESP) events accompanying interplanetary shocks associated with geo-effective interplanetary coronal mass ejections (ICMEs). The basis for this claim is our recent finding that (i) impulsive beam-like electron events are injected into the solar wind some 10 minutes after the associated solar electromagnetic (EM) emission centered on W70, because (ii) they are probably accelerated by CME-driven coronal shocks. We will exploit this close link between near-relativistic electrons and coronal shocks by: (1) analyzing their relation to prompt SEP ion events; (2) establishing the differences between impulsive near-relativistic solar electron events from the western hemisphere and those from near central meridian; (3) examining whether the central meridian electron events are good predictors of halo CMEs and Earth-directed ICMEs with their associated interplanetary shocks and ESP events; and (4) identifying any solar-cycle dependence in relations (1), (2), and (3). Finally, (5) we will investigate the impact that these results may have on the planning for payloads and orbits of future Living with a Star missions.

Hindman, Bradley W. / University of Colorado, Boulder
Developing Rapid Helioseismic Mapping of Evolving Solar Subsurface Weather and Magnetic Structures for SDO

The high spatial and temporal resolution data to be provided by the Solar Dynamics

Observatory (SDO) will lead to a new era of discovery about local dynamics and structure within the highly turbulent solar convection zone. Recently, local helioseismology applied to data from SOI-MDI on SOHO has revealed large-scale flow fields within the upper convection zone that are spatially intricate and evolve on a variety of time scales, changing from day-to-day as well as more gradually with advancing solar cycle. These weather-like flow patterns, now referred to as Solar Subsurface Weather (SSW), are crucial elements in the establishment of the sun's differential rotation and in the distribution and evolution of magnetic fields that emerge at the surface. The helioseismic imager aboard SDO will likely have fourfold better resolution than the full-disk field of SOI-MDI. This increased resolution coupled with uninterrupted observing will result in massive data sets (about 1 TB/day) and will present major challenges to measure SSW in a timely and continuous fashion. We propose to develop rapid ring-diagram analysis techniques capable of keeping pace with the data rate while mapping the flows over most of the solar disk and much of the near-surface rotational shear layer. We have identified three tasks necessary to achieve these objectives. The first is to characterize the flow properties at the high spatial and temporal resolution available with SDO. Using the high-resolution field of SOI-MDI as a proxy for SDO data, we will apply ring-diagram methods to a dense mosaic of tiles to study the spatial and temporal variability of SSW and to assess how these large-scale flows are modulated by the presence of magnetic structures. The second task is to develop new 3-D inversion procedures which take advantage of both small and large analysis tiles in order to observe SSW with the highest spatial resolution possible while simultaneously sampling deeply below the surface. The third task is to coordinate comparisons between ring-diagram, time distance, and correlation tracking methods. These tests will help establish the sensitivity and robustness of these complementary procedures to probe local dynamics. These efforts must start soon in order to develop, test, and implement the programs before SDO becomes operational.

Hood, Lon L. / University of Arizona, Tucson
Observational and Mechanistic Model Studies of the Quasi-Decadal Oscillation

Objectives: Our primary objective is to analyze selected satellite remote sensing data sets for the purpose of determining the stratospheric response to decadal solar ultraviolet variations. A secondary objective is to investigate theoretically mechanisms by which the equatorial quasi-biennial wind oscillation (QBO) may be modulated by decadal solar UV variations. The analytic approach will consist of (1) analysis of intercalibrated satellite ozone profile, column ozone, and temperature data sets extending through the current solar maximum; (3) empirical studies of the extent to which the solar cycle variation of lower stratospheric ozone and temperature may be a consequence of a solar-modulated QBO; and (4) applications of the NRL CHEM2D photochemical transport model, which includes a self-consistently calculated QBO. Significance: The observational component of the proposed work will provide more reliable constraints on general circulation models that are currently being applied to determine the effect of solar variability on long-term climate change. Because of the dominant role of the QBO in determining stratospheric interannual variability, the theoretical component can lead to a better understanding of how decadal solar variability can modulate circulation in the lower stratosphere and upper troposphere. Accomplishments: New Proposal. However, with prior funding under the Solar Influences on Global Change program, we have (a) compared our earlier estimates of the solar cycle variation of stratospheric ozone with those calculated by a representative GCM with parameterized chemistry; (b) reported additional statistical evidence for a solar modulation of the QBO; and (c) begun an investigation of how a solar-modulated QBO may explain a significant part of the solar cycle variation of lower stratospheric ozone. Citations: (1) Hood, L., and B. Soukharev, The solar component of long-term stratospheric variability: Observations, model comparisons, and possible mechanisms, extended abstract for SPARC 2000, Mar del Plata, Argentina, November, 2000. (2) Soukharev, B. and L. Hood, Possible solar modulation of the equatorial quasi-biennial oscillation: Additional statistical evidence, J. Geophys. Res., v. 106, 14855-14868, 2001. (3) Hood, L., The solar cycle variation of total ozone: Dynamical forcing in the lower stratosphere, J. Geophys. Res., v. 102, 1355-1370, 1997.

Krall, Jonathan / Naval Research Laboratory
Measurement and Modeling of Geoeffective Coronal Mass Ejections and Magnetic Clouds

We propose a three-year program to apply a numerical flux-rope model of coronal mass ejection (CME) events to Earth-directed "halo" and "partial halo" CME events, which are a class of geoeffective CMEs. This flux-rope model of CME events has been extremely successful in quantitatively reproducing the observed dynamics (size, position, velocity) of more than 15 "flux-rope CME" events and in quantitatively reproducing magnetic cloud properties in interplanetary space. To date, model results have not been compared to halo CME events which are both difficult to measure, because they tend to be faint, and difficult to interpret, because the velocity of the CME towards the observer cannot be measured directly. Two results from our previous data-model comparisons indicate the utility of extending these efforts to include Earth-directed CME events: 1. Synthetic coronagraph images of model flux-rope CMEs show that, when launched towards the observer, the model configuration reproduces the halo or partial halo often seen in CME observations. 2. The model shows that, as the underlying magnetic flux-rope structure of a typical flux-rope CME expands into interplanetary space, it matches typical magnetic cloud data in terms of size, density, temperature, and magnetic field configuration. In the present study, we will extend the methodology that was used in the quantitative modeling of limb events to address Earth-directed CME events. The result, for each event, will be a quantitative physics-based interpretation of the event and a prediction of the size, density, temperature, and magnetic field strength of the corresponding magnetic cloud. These predictions will be compared to magnetic cloud data. The overall purpose of this study is to aid in the interpretation of halo-CME event data and corresponding magnetic cloud data so as to better predict the geoeffectiveness of these events.

Lepping, Ronald L. / NASA/Goddard Space Flight Center
Magnetic Cloud Induced Magnetic Storm Intensity and Timing: Near Real Time Prediction for Optimum Future Years

A)Science Objectives/Strategy: The primary objectives of this investigation are fourfold: (1) to augment statistical studies of the relationships between interplanetary magnetic clouds (its IMF Bz in particular) and magnetic storms that we and others have found in the past for use in storm predictions from solar wind data, (2) to modify a force-free magnetic cloud model in two ways for future use in helping to predict, in near real time, what the trailing part of a cloud should be from data in the early part of the cloud (this part will require past WIND data and some IMP 8 data) and the development of the model's (``inverse") use in identifying clouds, (3) to combine the two parts above to develop a prescription that connects observations of the early part of the clouds features to predict minimum Dst and its occurrence-time to give many hours predict time (_t) for standard size clouds, (4) to study the differences between magnetic storms caused by other than magnetic clouds and those that are. The two modifications of the cloud model will be to accommodate any "sample" rate of input field, besides the grossly averaged data used to date and to account for expansion by using the observed speed gradient across the cloud. The resulting prescription hopefully will be suitable to data from an upstream solar wind monitor, such as ACE (or perhaps WIND at some later date), but we stress that ACE data will not be needed for this study; then the predict time is _t + 1 hour, typically, if the spacecraft is indeed at L1. In the process of developing these relationships a greater understanding of the timing of interplanetary features in influencing the resulting storm is expected, especially for dual-phase magnetic storms which are not well understood. The next few years are an optimum time to employ such a prescription, because the north-to-south kind of cloud is most probable giving the added advantage of part (2)'s study above. South-to-north cases will occur and will also be studied. B) Recent Progress: It is well known that geomagnetic activity depends on the interplanetary magnetic field (IMF) Bz in the solar wind plasma interacting with Earth's magnetosphere. We have shown that there is an unusually high correlation between storm intensity (measured by minimum Dst) and Bz-minimum associated with magnetic cloud events [Wu and Lepping, 2001a]. And the correlation of Dst vs. Bz increases dramatically when the solar wind speed is faster than 600 km/s.

Liewer, Paulett C. / Jet Propulsion Laboratory
Interpretation of Coronagraph CME Observations using MHD Modeling and Synthetic White Light Images

The goal of this research is to understand the structure and dynamics of CMEs and their propagation through the corona from the Sun to 30 R(sun), the edge of the LASCO coronagraph field of view. Specifically, we will determine the relationship between the evolving CME density, as seen in projection in LASCO images, and the underlying magnetic structures of the CME and corona. At present, it is not known whether the bright leading edge of a CME represents compressed streamer plasma or overlying loop material or some combination. Part of the difficulty in interpreting white light images is due to line-of-sight and viewing geometry effects. To accomplish the goals, we will use time-dependent 3-D MHD modeling of CMEs to interpret coronagraph images. We will model specific CME events observed by LASCO near solar minimum starting with a realistic pre-event corona computed using observed photospheric fields (synoptic magnetograms) as boundary conditions. The density of the pre-event corona will be determined from LASCO observations by inversion. This will be the first such use of a 3-D MHD code to model the evolution of specific CME events propagating in a realistic corona. Using the Thomson scattering formulas, synthetic white light images will be computed from the MHD model and compared with the LASCO images to verify the model. CME dynamics are controlled by the magnetic fields, and the verified model can be used to relate the observed density structure to the underlying CME and coronal magnetic fields. We will use the sophisti-cated adaptive grid BATS-R-US MHD code, developed at the University of Michigan, which is well suited to handle the multiple spatial scales in this problem. The work is a collaboration between scientists at JPL, the University of Michigan, and the Naval Research Laboratory, combining their complementary skills. This work will contribute to understanding the propagation of CMEs and thus contributes directly to the LWS goal: building the necessary scientific understanding of the connected Sun-Earth system to effectively address effects of solar variability on life and society. Specifically, the work will develop new models for describing solar and geospace "disturbances that may affect human technology," and the model will be made available to the community. The work will significantly increase the science return from the SOHO/LASCO images by relating the white light density observations to the driving magnetic fields.

Linker, Jon A. / SAIC
Case Studies of CME Events: A New Application of MHD Modeling

A key goal of the Living With A Star program is to understand how solar activity influences the Earth and its space environment. Coronal mass ejections are the primary cause of large, nonrecurrent geomagnetic storms at Earth and are a critical link between solar and geomagnetic activity. Models that can predict the initiation and evolution of CMEs are essential to the success of Living With A Star. At a minimum, such a model must be self-consistent, fully three-dimensional, use available data such as magnetograms as input, and predict the observable effects of CMEs (as seen in emission and white-light images, for example). The ingredients for such a model exist, but the capability to model actual CME events has not yet been demonstrated. We propose to develop such a model and test its fidelity by simulating two CME events (May 12, 1997 and September 12, 2000) in great detail. While our focus will be on comparing with available data from these events, our model will be applicable to future missions such as STEREO, Solar-B, and SDO. We will perform a series of magnetohydrodynamic (MHD) computations for each event to investigate the underlying cause of the CME and its subsequent manifestations in the solar corona. A primary aspect of our project will be to directly test our model predictions against available data from SOHO and Yohkoh; we will use our improved thermodynamic MHD model so that simulated emission in EUV and soft X-rays can be computed and compared with observations. The results from these studies will be made available on the Web so that other researchers can access and further analyze the simulation results.

Metcalf, Thomas R. / Lockheed Martin Solar & Astrophysics Lab
Observations of the Magnetic Free Energy in Active Regions: the Energization of Solar Activity

The magnetic field permeating the solar atmosphere governs much of the structure, morphology, brightness and dynamics observed on the Sun. The magnetic field, especially in active regions, is thought to provide the power for energetic events in the solar corona, such as solar flares and Coronal Mass Ejections (CME) and is believed to energize the hot coronal plasma seen in EUV or X-rays. The question remains what specific aspect of the magnetic flux governs the observed variability; we propose that to directly understand the role of the magnetic field in energizing the solar corona, it is necessary to measure the free magnetic energy available in active regions. We have now demonstrated (with support from a previous NASA grant) the feasibility of making temporally resolved measurements of the magnetic free energy above active regions. We have shown that the chromospheric magnetic flux vector, measured high enough above the photosphere so that the magnetic field is force-free, renders the magnetic virial theorem applicable. We are now in a position to fully exploit this new tool. The goal is to determine the physical changes which cause variations in the magnetic free energy. Ultimately, we hope to make advance predictions of solar activity by observing variations in the available magnetic energy.

Morrill, Jeff S. / Naval Research Laboratory
Sources of Solar Irradiance Variability: 200-400nm

The proposed research will examine the sources of solar spectral irradiance variability in the 200-400 nm wavelength range and how the variability of these sources impacts our ability to explain the observed full-disk spectrum. This will involve the analysis of high resolution (~0.01 nm) spectral observations made by the NRL HRTS-9 rocket and

SKYLAB spectrograph. The HRTS observations have a spatial resolution of ~ 1 arc-second and the SKYLAB spectra are averaged over spectrograph slit (~60x1 arc-second^2). The three main topics to be examined in this study will be: (1) Use a 3-component model with HRTS-9 plage and sunspot contrast to estimate solar spectral irradiance variability in the region near MgII (283 +/-3 nm) and compare with SUSIM and SOLTICE observations. (2) Use SKYLAB spectral observations in the 200-400 nm range to determine wavelength dependent contrast of plage and contrast variation within the quiet sun. (3) Use above model to compare predicted vs observed intensity over 200-400 nm range.

Riley, Pete / SAIC
Understanding the global structure and evolution of coronal mass ejections in the solar wind

We propose to use a new combined, global MHD model of the solar corona and inner heliosphere to interpret ACE and Ulysses plasma, magnetic field, and composition measurements of coronal mass ejections (CMEs) in the solar wind during various phases of the solar cycle: SAIC's coronal model will be used to initiate the disturbance and model its evolution to 20Rs and NOAA/SEC's heliospheric model will follow the evolution from 20Rs to 5 AU. The model results will be used to provide a global context with which to interpret in situ observations, and allow us to address fundamental issues concerning the origin, topology, and evolution of CMEs. In particular, we will address the following questions: - What are the fundamental evolutionary distinctions between CMEs and magnetic clouds? How do they relate to the concepts of "simple" and "complex" ejecta? - Under what conditions is the force-free approximation valid for CMEs? When, where, and why does it break down? - What is the relationship between the 3-part structure of CMEs seen in coronagraph observations and their interplanetary counterparts? - Do high-latitude CMEs (as observed by Ulysses) represent a distinct class of events? - What processes control the solar connectivity of field lines embedded within CMEs? - How do the properties of the ambient solar wind modify the evolution of ejecta? In particular, how does CME evolution differ at solar maximum from solar minimum? - What are the global morphologies of the so-called "double" flux ropes and "cannibal" CMEs? By exploring how different types of transient phenomena are initiated and evolve, and comparing with observations, we may also be able to resolve a long-standing controversy on whether there are two (or more) intrinsic classes of CMEs. Our team includes key personnel from the magnetometer, plasma, and composition instruments on board both ACE and Ulysses. The solar and heliospheric physics groups at SAIC and NOAA/SEC have maintained a successful history of developing sophisticated MHD codes and applying them to fundamental problems concerning CME initiation and evolution. As part of this investigation, we will make the results of our simulations available to the scientific community via the web.

Rusch, David W. / University of Colorado, Boulder
An Investigation of the effect of solar variability and particle ionization on the Earth's middle atmosphere

Upper atmospheric (upper stratosphere, mesosphere, thermosphere) variability is caused by processes related to the Sun and the magnetosphere from above, and natural and anthropogenic forcing from below. Changes in mesospheric composition, including NOx, ozone and temperature result from the complicated interactions of these forcings. We will use two and three-dimensional models to explore the known history of upper atmosphere changes with the goal of separating the natural from the anthropogenic. . We propose a model study of atmospheric properties, as influenced by known forces, including the 11-year solar variability, and a rigorous comparison with the available satellite and ground-based data sets. This study is made possible by the availability of data sets on atmospheric composition and structure extending back in time.

Ruzmaikin, Alexander A. / Jet Propulsion Laboratory
Modeling of Solar Influences on Atmospheric Dynamics

Our goal is to understand mechanisms by which weak solar variability can affect terrestrial global climate. We propose to investigate how solar changes influence the long-term dynamics of the atmosphere. Our objectives include 1) development of a simple model of atmospheric dynamics based on interaction of planetary waves with zonal flows in the stratosphere 2) investigation of different types of forcing of this dynamics 3) comparison results of modeling with observations and General Circulation Models To accomplish these objectives we will use numerical modeling and data analysis. This proposal addresses one of the main goals of the Living With a Star Program and this AO of "improving our understanding of the effects of solar variability and disturbances on terrestrial climate change" by modeling solar influences on climate. The results can be used for the formulating science objectives for possible future missions.

Scherrer, Philip H. / Stanford University
Heliotomography Tools for Studying Interior Sources of Solar Activity

This proposal is to develop tools to allow exploitation of the promise of acoustic tomography (heliotomography) of the solar interior for the LWS program. This will allow substantial improvement of our understanding of physical processes inside the Sun and mechanisms of solar variability. Heliotomography is a technique for inferring the 3-D structures and mass flows by observing packets of acoustic waves propagating through the solar interior. The development of robust tools for heliotomographic inferences is required for monitoring active processes in the solar interior to meet the demands of Living with the Star. These analytical tools (theoretical, modeling, and data analysis) tools will provide diagnostics for the internal structures as sunspots, active regions, and complexes of activity which play crucial role in solar variability, allow us to investigate dynamo processes in the convection zone, and lead to new methods for space weather forecasts. The tools will be prepared for real-time analyses of the LWS/SDO data and will be tested using the SOHO/MDI data. The initial analysis will focus on studying properties of emerging active regions and evolution of sunspots and active regions in the upper convection zone prior to strong CME and flares.

Stein, Robert F. / Michigan State University
Local Solar Magnetic Fields

The goal of this research is to understand solar variability produced by small (granule to supergranule network) scale magnetic fields. We will model the small scale local solar dynamo to determine the behavior of magnetic flux tubes at the surface of the quiet Sun. The results will provide the needed input boundary conditions for studying the behavior of the chromosphere and corona driven by flux emergence, motion and disappearance at the photospheric level. We will accomplish this by performing realistic magneto-hydrodynamic simulations of the solar photosphere and upper convection zone (down to a depth of 10-20 Mm) on the scale of supergranulation. The results will help us interpret the observations from SOHO and SolarB, and assist in the design of SDO and the ATST. Our realistic simulations of non-magnetic solar convection agree well with observations of photospheric line profiles, the granulation spectrum, p-mode frequencies and excitation. They have enabled us to understand the p-mode driving mechanism, surface effects on the p-mode frequencies, the impact of stratification on solar convection, and the non-local driving of solar convection.

Townsend, Lawrence / University of Tennessee
Advanced Warning Methodologies for Solar Particle Event Radiation Exposures

Human exploration and development of space requires consideration of the risks associated with acute radiation exposure to humans and equipment. Previous work has shown large that Solar Particle Events (SPE) can deliver doses to critical human body organs in excess of 10 Gy at dose rates exceeding 1 Gy-h-1 over several hours. Restriction of operations, necessary to maintain astronaut exposures at or below acceptable levels for long duration, deep space missions, could adversely impact crewed space missions. Excessive doses to equipment such as electronic components can render them temporarily or permanently inoperative and could also imperil crewed missions. SPE dose-time profile forecasting models could provide advanced warning of mission-threatening situations to mission controllers and commanders. Current SPE forecasting methodologies consistently overestimate the occurrence of large SPE. While conservative from a radiological risk perspective, such overestimates can unnecessarily restrict operations. The proposed research will investigate innovative forecasting methodologies utilizing neural networks and Bayesian inference techniques, with the possibility of combining these methods. Preliminary investigations using these techniques individually have demonstrated the potential for accurately forecasting SPE dose-time profiles early in the evolution of an event, using dosimeter readings obtained in the early stages of the event. Objectives for this research include: (1) Added testing of exisiting neural network and Bayesian inference methods beyond preliminary work completed to date (2) Extension of neural network methods to provide dose versus time profile information (3) Extension of Bayesian inference methods to use dose rate data rather than dose data to make predictions (4) Investigation of the capabilities of an advanced warning system which combines a neural network and Bayesian inference methods.

White, Warren B. / University of California, San Diego
Quantitative Assessment of the Integrated Response in Global Heat and Moisture Budgets to Changing Solar Irradiance on Decadal, Interdecadal, and Secular Time Scales

We propose to conduct a quantitative assessment of the responses in basin- and global-average upper ocean and lower atmosphere heat and moisture budgets to decadal and interdecadal signals, and the trend, in the Sun's radiative forcing from 1950 to 2000. We will update the Scripps Institution of Oceanography (SIO) reanalysis of upper ocean temperature profile dataset from 1950 to 2000 to establish the global patterns of DAT and DHS anomalies, and we will utilize the National Centers for Environmental Prediction (NCEP) reanalysis of tropospheric variables over the same 50-year record to establish global patterns of troposphere temperature, moisture, clouds, winds, etc., and estimate air-sea fluxes of heat, moisture, and momentum. This will allow us to diagnose basin- and global-average heat and moisture budgets from the top of the main thermocline to the bottom of the tropopause. We will verify the Pacific-average DHS budget by closing it the Ocean Isopycnal (OPYC) model (Auad et al., 1988 a, 1998b), the latter driven by the NCEP heat, moisture, and momentum fluxes (Kalnay et al., 1996).