Living with a Star Targeted Research and Technology
Abstracts of selected proposals.
(NNH06ZDA001N-LWS)

Below are the abstracts of proposals selected for funding for the Living with a Star Targeted Research and Technology program. Principal Investigator (PI) name, institution, and proposal title are also included.

Valentyna Abramenko/Big Bear Solar Observatory
Distribution and dynamics of the solar magnetic flux in the photosphere and heliosphere

This proposal is being written in response to a request by the TRT focus team on "Solar and Heliospheric Magnetic Field" led by T.H. Zurbuchen, University of Michigan. The team, and especially its lead, have encouraged to propose for a third year of funding to allow a successful completion of the focus team work. The need for this proposal arises from two reasons. First, our initial proposal extended only over two years. We are well on the way to achieving the statements of work (SOW) for this initially proposed research. Second, in response to team-objectives, we have adjusted our SOW to be of maximum help to the focus team and our work is now well connected to other parts of the team-work.

During the first year of our collaboration we have analyzed dynamics of emergence of new dipoles inside coronal holes and in adjacent quiet-Sun areas. We have shown for the first time that the dipole emergence rate of the magnetic flux inside coronal holes is suppressed as compared to the quiet sun areas. This finding agrees with the idea that coronal holes are formed at location where the dipole emergence rate is low and therefore open magnetic flux can be accumulated at these places (theory of the coronal holes formation and solar wind acceleration, Fisk 2005). This theory suggests that reconnection between open magnetic flux and closed magnetic loops is an essential diffusion mechanism for open filed lines.

We are currently improving and modifying our existing algorithms and numerical codes to calculate power spectra of magnetic field fluctuations (both spatial and temporal) as well as high statistical structure functions, which would allow us to derive flatness functions and filling factor and estimate intermittency of the magnetic field both in the photosphere and in the solar wind. This analysis will then be compared to the results of other team members (both observational and theoretical). Our funding is likely to run out before the completion of this collaboration, which is an important part of the work by the focus team.

During the third year, we will study magnetic flux distribution in the photosphere both inside and outside of coronal holes. We intend to apply our techniques to photospheric and solar wind measurements. Conclusions and parameters obtained from the study will be used as input date and/or constrain the models of coronal hole formation and solar wind acceleration developed by our focus team.

Robert Benson/NASA Goddard Space Flight Center
Characterizing the composition of large mid-latitude topside-ionospheric/plasmaspheric gradients

The overall goal will be to characterize the latitude and altitude dependence of large mid-latitude ionospheric electron and ion density gradients associated with outer-plasmaspheric structures. Specific objectives are to (1) delineate the differences between the sharp low-latitude walls of mid-latitude ionospheric Ne, H+, and He+ trough structures and the gradients of isolated plasma patches, (2) determine the altitude variations in these gradients from the O+ dominated ionospheric F region up to higher altitudes where lighter ions can dominate, and (3) relate these ionospheric Ne and ion boundaries to magnetospheric plasmapause observations during the same time period. Achieving these objectives will provide an understanding of the basic physics associated with these boundaries. This understanding requires knowledge of the ion composition that determines the underlying structure of the vertical Ne profiles.

The approach will be to use latitudinal cuts of topside sounder vertical Ne profiles, from both archived digital files and recently-produced digital topside ionograms, which can be used to infer ion composition changes from scale heights, in conjunction with archived satellite ion-spectrometer measurements to determine the altitudinal dependence of latitudinal structures in the midlatitude trough region for Ne and each of the important ion species. The rationale for using early archived data is to be able to subject a time interval when there were coincident vertical ionospheric Ne profiles, and a wealth of ionospheric and magnetospheric ion-composition data and magnetospheric electric-field data, to current analysis techniques based on a better understanding of ionospheric/magnetospheric physics. The structures of the low-latitude boundaries of the He+, H+ and Ne troughs, and the boundaries of detached narrow plasma enhancements, will be compared day and night as well as under differing geomagnetic storm conditions to quantify their interrelationships. Searches will be made for the composition signatures of ionospheric plasmatails and the conditions under which they occur. Physical models will be used to undertake detailed case study comparisons to understand the physical processes that control the ion densities along multiple magnetic field lines from the ionosphere to the plasmasphere. The topside Ne profiles and ion information will be used to include a representation of large gradients in the International Reference Ionosphere (IRI) in the mid-latitude topside ionosphere where it is in great need of improvement.

Our objectives support the LWS goal "to develop the scientific understanding ... to effectively address those aspects of the Heliophysics science that may affect life and society" in that a knowledge of mid-latitude topside ionospheric structures is needed to mitigate the ionospheric impacts on advanced technological systems, such as GPS positioning, where the ionospheric effects on trans-ionospheric radio propagation is often the limiting factor on overall system performance. It supports the LWS TR&T Focused Science Topic "a" (Investigate the Global Distribution, Sources and Effects of Large Electron Density Gradients at Middle and Low Latitudes) in that it aims to "produce an improved scientific understanding and characterization of large electron density gradients in the Earth's middle and low latitude ionosphere, leading to improved models that can generate predictions of societal value." Since the investigation (1) exploits the data analysis of large mid-latitude gradient features, (2) includes theoretical analysis of how these features are generated, (3) improves a physical model to relate ionospheric and magnetospheric features, and (4) enhances the IRI empirical model by providing more data that will lead to improved prediction capabilities, it addresses all four of the "types of solicited objectives" listed under the LWS TR&T Focused Science Topic "a".

Aaron Birch/Colorado Research Associates, NWRA, Inc.
Predicting Active Region Emergence, Evolution, and Flare Productivity using Local Helioseismic Measurements and Discriminant Analysis

Prediction of solar active region emergence, growth, and energetic activity is central to the objectives of LWS and is needed for determining periods of time which will be safe for extra-vehicular activity by the crews of the ISS, Space Shuttles, and future long term missions. In order to address the Focused Science Topic "predict the emergence of solar active regions before they are visible," we propose a comprehensive study consisting of three main components: (1) local helioseismic measurements of preemergent and emerged active regions using MDI/SOHO and HMI/SDO data; (2) semi-analytical and numerical modeling of the helioseismic signatures expected for preemergent and emerged active regions; and (3) statistical searches for helioseismic predictors of active region emergence, evolution, and energetic activity.

The modeling component will be to estimate the helioseismic measurements that would be expected for different flow, sound speed, and magnetic field configurations associated with preemergent and emerged active regions, including the effects of surface magnetic fields. The identification and removal of surface effects will be important in detecting preemergent active regions.

The statistical studies will be based on Discriminant Analysis (DA), a statistical method for determining how to best distinguish between samples of two or more mutually exclusive groups in a given parameter space such that a new measurement can then be classified as belonging to a particular group.

The NRA describes "the prime measure of success for this work will be to demonstrate a statistically significant ability to predict the location of new active regions before they are visible on the surface of the Sun and also their evolution." The application of DA to search for statistically significant helioseismic predictors of active region emergence and evolution provides a direct test of this prime measure.

Benjamin Chandran/University of New Hampshire
Stochastic particle acceleration in solar flares

The acceleration of particles to energies exceeding 50 MeV in solar flares is a long-standing problem and one of the Focused Science Topics of NASA's 2006 Living-With-a-Star (LWS) program. This proposal addresses one of the leading theories for particle energization in flares, namely stochastic particle acceleration. In this theory, turbulent waves are excited in the flaring region by magnetic reconnection and the ideal fluid motions that arise as the magnetic field relaxes to a new configuration. The energy in these waves undergoes a turbulent cascade to small scales, resulting in high-frequency waves that accelerate particles to high energies through resonant wave-particle interactions. If the power spectra of these waves have the right properties, stochastic acceleration can explain many of the observed features of flares, including the acceleration time scales, the energy spectra of different particle species, and the highly enhanced abundance of helium-3 relative to helium-4 in the accelerated particle population. However, there is still no predictive theory for the turbulent power spectra of waves on the Alfven/ion-cyclotron and fast-magnetosonic/whistler branches of the dispersion relation in flaring regions. The determination of these power spectra is the most important unsolved problem for the stochastic-acceleration model, and is the focus of this proposal. Building on previous work by the PI and co-I, we will carry out weak turbulence calculations and direct numerical simulations to determine the power spectra of the above-mentioned waves for solar-flare conditions. A notable feature of this turbulence research is its extensive use of analytic theory in addition to numerical simulations, which will lead to highly detailed quantitative results, a theoretical framework that can be applied by other investigators, and a clear physical picture of the energy cascade mechanisms. We will use these power spectra to determine the acceleration times and energy spectra of different particle species as a function of the overall turbulence amplitude (i.e., the rms velocity at the largest scales) using quasilinear theory to treat the particle-acceleration process. We will then compare our results to x-ray, gamma-ray, and in-situ particle measurements. By determining the power spectra of the different wave modes in solar-flare conditions, our work will provide key missing information that is essential for assessing the importance of stochastic acceleration in solar flares, and for determining the contribution of flare-accelerated particles to large solar-energetic-particle (SEP) events observed at Earth.

John Fontenla/University of Colorado
Understanding the sources of the solar spectral and total irradiance variability and forecasting tools

We propose new research into the physical origins of the UV solar spectral irradiance variations and their contribution to the total. This research will expand tools we have developed to relate the visible and infrared solar spectral irradiance variations to features observed on the solar disk, namely active regions and network, through semi-empirical atmospheric models constructed to explain their spectra. Our approach is based on the physical processes of non-Local Thermodynamic Equilibrium (NLTE) radiative transfer and observational diagnostics of physical parameters characterizing the solar atmosphere. This approach uses high-quality solar images at key wavelengths together with our published semi-empirical models, and has been very successful in reproducing observed spectral irradiance variations for lambda>400 nm during the last few years.
We propose here extending our techniques to the UV solar spectral irradiance, in the range 100-400 nm, and developing forecasting tools better than the currently available proxy methods. This wavelength range displays important variability and is critical for

photochemical reactions and heating of the Earth's upper atmosphere and those of other planets.
By using image analysis and spectral irradiance synthesis in combination with far-side helioseismic imaging and data analysis of Lyman alpha backscattering from the interplanetary medium (observed by the SOHO/SWAN instrument) we will be able to infer the radiation spectra in any direction and forecast the solar irradiance based on the knowledge of the distribution and radiative characteristics of the active regions. Our research can produce very high spectral resolution (up to $\lambda/\Delta\lambda \sim 10^6$) and greatly improved predictions of UV spectral irradiance that can be used modeling the Earth's atmosphere .
This research has important applications for understanding long-term spectral and total irradiance trends, for connecting solar dynamo and magnetic field studies with the Sun's radiative output, and for short-term (~2 weeks) forecasting of the Earth radiative environment that is critical for predicting satellite drag.

John Foster/MIT Haystack Observatory
Ionospheric Redistribution: Storm Enhanced Density as a Source for Ion Outflow in the Cusp and Polar Cap

This is a multi-instrument investigation using both ground and space based systems to investigate the characteristics and dynamics of the ionospheric source plasmas in ion outflow/acceleration regions at the base cusp field lines and in the polar cap. An accurate specification of source plasma characteristics is need to model and understand the injection of ionospheric ions into the magnetosphere during storms. In particular, we will examine the conditions under which lower-latitude enhanced-density ionospheric plasma is supplied to the ion outflow and acceleration regions, and the conditions under which this material is drawn into the polar cap, forming a polar tongue of ionization (TOI). We will employ a wide range of available ground based [incoherent and coherent scatter radar, Global Positioning System (GPS) receivers] and DMSP in-situ satellite diagnostics. The results of our studies will significantly advance knowledge of the temporal evolution and ultimate impact of stormtime ionospheric restructuring on the source regions providing outflow of heavy ionospheric ions to the magnetosphere.
We will combine GPS TEC global maps with SuperDARN convection velocity determinations to investigate the role of electric field variability in structuring the cold source plasmas as it enters the cusp and polar cap. Incoherent scatter radar observations will provide vertical profiles of the redistributed ionospheric material in the mid-latitude source region, the cusp, and polar tongue of ionization. This will provide an accurate specification of the source plasmas feeding the ion-outflow mechanisms and will contribute to Team efforts attempting to model these processes.
Questions to be addressed include:
1. Under what solar wind and ionospheric/magnetospheric conditions does the SED plasma enter into the polar circulation pattern, and under what conditions does it not?
2. Is an active subauroral SAPS electric field required to efficiently provide SED material as a source for TOIs, and if so is there an identifiable threshold for this mechanism?

3. During events where a TOI forms, what is the spatial and temporal variation of the low altitude SED sunward plasma flux? How does this compare with the ionospheric material which continues onward into the polar cap general circulation as TOI?
4. How does the low altitude density distribution, plasma temperature, and plasma composition of ionospheric source material change as this material moves from the mid-latitude SED plume sunward into the cusp region and subsequently into a polar TOI?
5. Are there cusp velocity / electric field structures and/or fluctuations at ionospheric heights which are identifiable as causing plasma structuring? Do these structures enhance flux outflows?

Marc Hairston/University of Texas at Dallas
Study of conjugate polar ionospheric storm response during typical and extreme solar wind conditions using ACE and DMSP satellite observations

It is well known that solar wind conditions (the IMF and the ram pressure) are, through the magnetosphere, the primary drivers of the ionospheric phenomenon in the polar region (cross polar cap potential drop, convection patterns, triggering of storms, etc.). What is not as well understood are the differences in these phenomena between the two polar ionospheres as they react to the same drivers. To first order it would appear that the phenomenon in the two hemispheres should be the same (such as the potential drop) or mirror images (such as the convection pattern). However this neglects the feedback role the ionosphere itself plays. During solstices there is a marked difference in the conductance between the sunlit summer pole and the darkened winter pole, so there should be a significant difference in the currents, the potential distribution, and the potential drop between the two hemispheres. To date there have been only a few limited observations that have addressed whether this asymmetry in the potential and potential distribution exists or not, so the question is still open. But with the observations from the plasma instruments on multiple DMSP spacecraft in polar orbit it is possible to select periods where we have simultaneous observations in both hemispheres. The upcoming launch of DMSP-F17 in fall 2006 combined with the ongoing mission of DMSP-F13 will give us, for the first time, a long-term dataset of simultaneous dawn-dusk polar passes in opposite hemispheres. We propose to identify these periods then compare the DMSP observations of the potential distribution, potential drop, polar cap size, field-aligned current, location of the auroral boundary, etc. with the solar wind drivers (IMF magnitude and orientation, ram pressure, etc.) measured by the NASA spacecraft ACE. The results will definitely answer whether or not there is a difference in the two polar ionospheric regions' responses to the solar wind drivers under both nominal and storm time conditions and, if there is a difference, how they are mediated by the magnetosphere and ionosphere. This proposal to the independent investigation component of the Living with a Star TR&T program will support the LWS goals by furthering the understanding of the solar wind-magnetosphere-ionospheric coupling and the storm-time response of the ionosphere to the solar wind drivers. In addition this work will make use of the NASA funded on-line databases of the ACE and DMSP data.

Erika Harnett/University of Washington
Advanced computer modeling of the lunar plasma environment in the dynamic terrestrial magnetosphere

This proposal seeks to use an advanced 3D multi-fluid model in conjunction with Lunar Prospector data to quantify the plasma environment when the Moon is in the Earth's magnetotail from quiet to storm conditions. The proposed work seeks use Lunar Prospector data from the magnetometer/electron reflectometer (MAG/ER) to first quantitatively validate the modeling and then develop a full 3D perspective of the Moon's near space environment under varying conditions within the Earth's magnetosphere. The multi-fluid model incorporates ion cyclotron and multi-ion species effects similar to hybrid codes but the fluid treatment enables grid refinement down to as small as 10 km can be achieved (or nearly an order of magnitude better hybrid codes). This high resolution is unique to the multi-fluid modeling, and will allow for incorporation of the lunar magnetic anomalies to determine how they modify plasma transport and acceleration on the back side of the Moon. The multi-fluid treatment is able to generate electron spectrogram to enhance comparison with data and is also able to incorporate the mixing of the different ions species, observations that Lunar Prospector was unable to make. These capabilities are unique to the proposed work and through the proposed data/model synthesis, we can develop a global 3D picture of the Moon/Earth interaction out of 1D satellite traces that will address three critical questions:

1. What are the the composition, energy, density, and velocity of ions near the Moon for (a) quiet conditions and (b) sub-storm/storm conditions?
2. What is the overall geometry of the cavity and wake region of the Moon, specifically what are the asymmetries of the wake for different incident terrestrial magnetospheric plasma conditions?
3. What role, if any, do the magnetic anomalies play in modifying the above?

This work addresses Strategic Sub-goal 3B by developing an understanding of the space environment around the Moon and the plasma acceleration processes that can lead to energetic particle populations in this region. The work also addresses Strategic Sub-goal 3C by quantifying potential radiation hazards with regard to human habitation on the Moon.

Rod Heelis/University of Texas at Dallas
Ionospheric Dynamics Associated with Large-Scale Density Gradients

We propose to utilize satellite observations, ground TEC measurements, and simple computational modeling to investigate the role of ExB drifts and neutral winds in the generation and evolution of electron density gradients at middle to low latitudes in the F region. The appearance of significant density gradients in the region produce large signal fades and loss of control tracking loops in GPS systems and thus the importance of recognizing under what conditions such degradation might appear is of great value. At middle latitudes the interaction between magnetospheric energy inputs, solar radiative inputs, and planetary rotation critically determines the dynamics of the plasma and large-scale spatial gradients in the ion density can result from vastly different dynamic histories of the plasma in neighboring regions. Thus the relevance of this investigation extends beyond the societal impacts of compromised communication and navigation systems to the more fundamental of NASA's strategic goals to understand the Sun and its effects on Earth and specifically how the near space environment responds to changes in the interplanetary medium produced by the Sun.

We will identify electron density gradients using two different techniques. Examination of a global distribution of total electron content derived from ground-based TEC measurements will provide a global perspective within the wide and variable spatial and universal time ranges of the available data. Latitude and longitude (local time) profiles of the ionospheric electron density, from the DMSP and ROCSAT satellites respectively, will provide a much higher spatial resolution but in a more limited spatial and universal time range. Together these two data sources provide many opportunities to identify plasma density gradients. In addition, the satellite data provide a detailed description of the dynamics of the plasma associated with the density gradients. From this data set we will establish the differences in the dynamics associated with regions of low and high density and how the transitions between the regions behave.
An ionospheric model, driven by ExB drift and neutral wind inputs can be used to conduct parameter studies to establish the relationships between these drivers and field-aligned plasma motions. Since these field-aligned perpendicular motions can be directly measured it is possible to infer the differences in neutral winds and ExB drifts that are associated with regions of low and high density. In this way the conditions for formation of large-scale gradients can be specified.

Frank Hill/National Solar Observatory
A Study of Seismic Signatures of Active Regions in Farside Imaging for Applications to Space-Weather

The investigators will conduct a comprehensive statistical study of the relation between the holographic seismic signatures of active regions and their magnetic and intensity configurations for further improvements in imaging active regions on the Sun's far surface and further extension of farside imaging to space weather and other applications.

The program we propose consists of two substantial parts: 1) Improvements in the calibrations of holographic seismic images based on the evaluation of nearside signatures, and 2) Application of holographic diagnostics, both nearside and farside, to simulations of active regions to be produced by a closely related program.

This study can be regarded as a continuation of a NASA-supported research that has extended farside imaging techniques to GONG observations covering the entire far hemisphere of the Sun and has substantially improved the quality of the original farside images, which initially covered less than half of the Sun's far hemisphere. The early stages of Part (1) have already commenced under the current NASA program, which is about to expire. This is based on the relatively simple assumption that the farside signature characterizes an "acoustic Wilson depression" proportional to the square magnetic field alone, which is already recognized as inadequate. The new program will take into account field inclination, and intensity and the underlying thermal anomalies these may signify in plages and sunspots. A realistic interpretation of the farside seismic signatures is crucial for improved space-weather applications, particularly for our understanding of the connection between farside signatures and prospects for major flares and Coronal Mass Ejections (CME). Part (2) will be conducted in close collaboration with CoIs at NWRA and Stanford, who will produce simulations of active regions for control applications of our farside imaging techniques. These are essential for a working assessment of the diffuse artifacts projected into farside images by active regions on the Sun's near surface. A comprehensive determination of the diffuse artifact is crucial to a practical extrapolation of changes in the global coronal magnetic field and the impact of active regions that emerge on the Sun's far surface, including an assessment of prospects for large flares and CMEs. It is, moreover, essential to the application of farside imaging to solar irradiance forecasting, which it is now heavily in demand. The program we propose will be conducted with CoIs and collaborators doing closely related theoretical modeling and simulations at NWRA and Stanford. We will also work closely with collaborators at LASP and the SOHO/SWAN project who are working on visible and UV irradiance forecasting.

James Horwitz/The University of Texas at Arlington
Auroral Ionosphere-Magnetosphere Plasma Transport with Alfvén Kinetic Effects

The central objective of this proposed effort will be to understand the interplay of ion and electron and wave dynamics in the field-aligned plasma transport along auroral ionosphere-magnetosphere flux tubes.

We will combine analysis of particle, wave and field observations from aboard recent spacecraft sampling the auroral ionosphere-magnetosphere coupling regions, with the coupling of an ionospheric plasma transport model with kinetic effects and a code for simulating the propagation and effects of Alfvén waves on electron energization, to synergistically explore key aspects of the physics of the high-latitude ionosphere-magnetosphere region extending from the ionosphere to approximately 1 RE altitude. The data utilized will include observations from POLAR, FAST, DMSP and other relevant spacecraft. One important outcome expected from this investigation is the distillation of new useful formulas for the ionospheric plasma outflows as functions of the principal drivers of these outflows. These formulas will be designed for convenient use by global magnetospheric modelers. These and all other projects within this proposal fit under the LWS TR&T targeted objective, T3b: Ionosphere-Magnetosphere plasma redistribution.

The mysterious beauty of the aurora fires the imagination and awe of all who view it. This project is significant because it will determine the dynamic interaction between ionospheric plasma outflow and Alfvén wave driven auroral electron acceleration and the complex auroral region plasma processes from the collision-dominated ionospheric E-region to collisionless regions at very high altitudes.

Qiang Hu/University of California, Riverside
A new approach to modeling three-dimensional non-force free coronal magnetic field

We propose to develop and test a new approach to deriving the three-dimensional non-force free coronal magnetic field structure from photospheric vector magnetograph measurements. The local structure in approximate magnetohydrostatic equilibrium above the photosphere is to be reconstructed, utilizing high-quality vector magnetogram which provides boundary conditions within its field-of-view.

Based on the Principle of Minimum Dissipation Rate, a general non-force free magnetic field can be expressed as the superposition of two linear (constant-α) force free field. The parameter, α, for each of the two linear force free field, can be determined by optimizing the requirement that the recovered transverse magnetic field components as the superposition of the corresponding components of the two linear force free field agree with the observed ones at the photospheric level. Further studies on optimizing such an agreement is proposed. Therefore, an optimal solution without the common force-free assumption is obtained by solving two linear force free extrapolation problems, in which only the normal component of the magnetic field at the lower boundary is known. The difficulties associated with such an extrapolation is well known. We will revisit these problems and propose alternative means to overcome them.

The proposed research has significant impact on LWS program and Heliophysics science, since studying solar coronal magnetic field is the key element in the understanding of solar magnetic activity. It is the driving force of the space weather effect, that is a key issue to NASA's new vision for space exploration. At the present time, new high-quality and high-resolution magnetograph data from both ground-based and space-borne instrumentations are becoming available. It is imperative to develop such a tool to meet the demands for quantitative analysis of solar coronal magnetic field.

Joseph Huba/Naval Research Laboratory
Modeling Large Scale Electron Density Gradients in the Low- to Mid-Latitude Ionosphere

A three-year program is proposed to develop a comprehensive modeling capability to study and understand the onset and evolution of large scale electron density structures in the low- to mid-latitude ionosphere. In particular we intend to address a number of critical science questions associated with this phenomenon:

- What physical processes control the spatial and temporal scales of large scale electron density gradient structures?

- What mechanisms trigger large scale density depletions? Gravity waves? Bottomside F region turbulence?

- What mechanisms suppress large scale density depletions? E region conductivity? Meridional neutral winds?

- What physical processes control the day-to-day variability of low-latitude ionospheric structures?

- What is the relation between equatorial spread F bubbles and large scale depletions that develop during storm-times?

These questions will be addressed using a newly developed two-dimensional equatorial spread F code NRLESF2 and an upgraded version of the three-dimensional NRL ionosphere model SAMI3. We will also use the coupled SAMI3/RCM model to investigate storm-time generation of large scale density gradients in the low- to mid-latitude ionosphere. To our knowledge, SAMI3 is the only comprehensive 3D ionosphere model capable of addressing the onset and evolution of large scale electron density gradients in the low- to mid-latitude ionosphere. The unique features of the code are (1) a non-orthogonal, nonuniform fixed grid that can highly resolve the post-sunset ionosphere on relevant spatial scales (e.g., 10s km zonally and few km in the altitude range 200 - 800 km), (2) a 2nd order, semi-implicit temporal scheme that can model the development of instabilities, and (3) the ability to resolve sharp gradients using a high-order spatial interpolation scheme (e.g., typically 8th order) using the distribution function method and the partial donor cell method as a flux limiter. Additionally, preliminary results from the newly developed model NRLESF2 show multiple bifurcations, secondary structure development, density `bite-outs' of over three orders of magnitude, and high speed flows within low density channels (few km/s). These results are consistent with radar observations and have not been reported in previous simulation studies of equatorial spread F.

The investigation of large scale electron density gradient structures in the low- to mid-latitude ionosphere is a Focused Science Topic in the NASA Living with a Star Targeted Research and Technology program. The proposed program directly addresses the following goals of this Focus Science Topic: (1) to develop models with the appropriate spatial and temporal resolution to simulate the relevant physical processes, and (2) to improve the characterization of the global distribution, dynamics, and lifetimes of large gradient features.

Thomas Immel/University of California, Berkeley
Investigation of Tropospheric Ionospheric Interactions

A new large-scale structure has recently been discovered in the equatorial ionosphere. The peak plasma density and separation of the two bands of the equatorial ionospheric anomaly (EIA) were found to vary significantly at equinox, with maxima in 4 sectors around the planet. No known topside driver has such a high spatial frequency, and it has been shown that the wave-4 structure corresponds well with the distribution of atmospheric tides forced mainly by persistent tropical precipitation during equinox. With this observation, a theory was developed that the electric fields are alternately enhanced and suppressed by a combination of these tidal components that propagate upward from the troposphere. This theory will be tested by sythesizing advanced models of atmospheric tides and the ionosphere. We propose to integrate the combined mean and tidal winds of the NCAR GSWM with the NRL SAMI3 model to self-consistently reproduce the dynamo electric fields that generate the dayside ionospheric fountain electric field and EIA. This is a significant modification of the SAMI code that will require close cooperation between the Berkeley and NRL groups. This work is required to understand the coupling between the troposphere and ionosphere that appears to occur globally on a regular basis.

Vania Jordanova/Los Alamos National Laboratory
A comprehensive self-consistent inner magnetosphere model

We propose to develop a comprehensive model of the inner magnetosphere that will include a kinetic ring current/radiation belt model coupled with a 3-D force balance model that calculates self-consistently the magnetic field and inductive electric field, and an MHD model coupled to an ionospheric model that calculates self-consistently the convection electric field. The individual models will be linked together by integrating them into the Space Weather Modeling Framework (SWMF) developed at the University of Michigan. Unique features of all models will thus be combined in obtaining a fully self-consistent inner magnetosphere (IM) model that takes into account the anisotropic plasma distribution. Such anisotropy is critically important for determining the onset of instability for various plasma waves which affect the dynamics of both ring current ions and radiation belt electrons. Our kinetic code treats these wave instability processes self-consistently with the evolving energetic particle populations. In the coupled model the dynamics of the ring current, plasmasphere, ionosphere, and radiation belts will be treated self-consistently with the evolving outer magnetosphere, driven by available information on solar activity. This will significantly improve the predictive capabilities of the model and is aligned with the strategic NASA goals and Science Outcomes 3B. The model results will be compared with in situ and ground-based data in order to constrain the free model parameters and improve the model accuracy. The main scientific aims of this proposal are:
1) To provide a specification and forecasting of the ring current ion composition, anisotropy, and energy redistribution during magnetic storms, a key objective of this LWS TR&T solicitation, Focused Science Topic (b) of the Targeted Investigations.
2) To provide a global specification of the magnetic and electric fields in the IM, and evaluate the effectiveness of various acceleration and loss processes on ring current and radiation belt variability as function of interplanetary conditions.
3) To determine electromagnetic ion cyclotron (EMIC) waves excitation and particle precipitation patterns as function of interplanetary triggers, and provide their distribution during various storm phases.

Shri Kanekal/University of Colorado
Relativistic electron dynamics during geomagnetic storms: energization, loss and global coherence

The aim of our proposed research is to understand the physics of acceleration, transport and loss of electrons in the Earth's outer radiation belt during geomagnetic storms. Specifically we propose to (i) quantify electron flux dynamics during geomagnetic storms over an entire solar cycle across all L shells, (ii) characterize global coherence emphasizing pitch-angle scattering leading to flux isotropization, and (iii) investigate the systematics of electron decay time-scales and the specific role of electron microbursts as a loss mechanism.
The results of our investigations will help determine the relative strengths of particle transport versus in-situ processes in electron energization. We will quantify the role of flux isotropization, i.e, pitch-angle scaterring during electron acceleration. Our results of electron decay times will help distinguish between various mechansism of pitch angle scattering leading to electron loss. We will also quantify the extent to which microbursts result in the depeletion of electron flux.

Our research will utilize observations made by multiple spacecraft including SAMPEX, Polar and HEO which provide a comprehensive coverage of the Earth's outer radiation belt. Our database covers an entire solar cycle and comprises measurements of electrons over a wide energy range. These spacecraft are in distinct orbits around the Earth and therefore provide a global picture of the outer zone.

Our proposed research directly addresses two major objectives of the LWS program:(a) to identify and understand response of the space environment to solar variability, and (b) to quantitatively connect this response to solar variability. A major objective of the TR\&T program is to understand the acceleration, transport and loss of radiation belt particles. Space environmental conditions affecting robotic and human exploration include the Earth's Radiation belts. Our proposed research is therefore highly relevant to the LWS and especially the TR\&T program.

Judy Karpen/Naval Research Laboratory
3D MHD Modeling of Flare Reconnection for Solar Energetic Particle Acceleration

Objective: to determine the connectivity changes, observable signatures, and energy budget of flare reconnection driven by a self-consistent solar eruption. Results can be used as input for particle acceleration models and compared with SEP and radio observations.

Methods: numerical simulations with ARMS, our massively parallel 3D MHD code with adaptive mesh refinement. Postprocessing with Heliospace and other software to determine field topology and predict observable signatures.

Significance: understanding the 3D reconnection process through modeling driven in a self-consistent and realistic manner is an essential component of a team approach to solving the flare particle acceleration problem.

George Khazanov/NASA Marshall Space Flight Center
Relativistic Electron Losses in the Outer Radiation Belt Via Their Interactions With EMIC Waves

The dynamics of the radiation belts (RB) have received considerable attention in recent years because of their impact on our technology-based society and because of the fundamental and unresolved scientific questions about transport, acceleration and loss of these particles. During magnetic storms, under certain conditions, relativistic electrons with energies ~1 MeV can be removed from the outer RB by Electromagnetic Ion Cyclotron (EMIC) wave scattering. Recent calculations suggest that pitch angle scattering via EMIC waves can compete with Dst effect as a mechanism for depleting relativistic electrons from the outer RB zone during the initial and main phases of a magnetic storm. These studies assumed only (or almost) parallel propagating EMIC waves. However there are growing theoretical and experimental evidence that such assumption could be severe and should be reconsidered in future studies of relativistic electron losses.

EMIC waves are generated by ion temperature anisotropy in the Earth's ring current (RC) and, therefore, the dynamics of RB, RC, and EMIC waves are intimately related. It is well known that the effects of EMIC waves on RC ion and RB electron dynamics strongly depend on such particle/wave characteristics as the phase-space distribution function, frequency, wave-normal angle, wave energy, and the form of wave spectral energy density. Therefore, the realistic characteristics of EMIC waves must be properly determined by modeling the RC-EMIC wave evolution self-consistently. This work is absolutely necessary to achieve the NASA LWS goal of predictive modeling of the growth and decay of the RB during the magnetic storms.

To quantify the EMIC wave effects on the RB losses, in order to properly address NASA LWS program concerns, a systematic and self-consistent studies of magnetosphere-plasmasphere-ionosphere RC/EMIC wave coupling are needed in order to provide EMIC waves forecast on a global scale and include corresponding wave-particle interaction processes in RB modeling. We propose a comprehensive theoretical study of EMIC waves and their interactions with relativistic electrons on a global scale based on our self-consistent RC/EMIC wave model that has been developed over the last five years [Khazanov et al., 2002-2006]. The central objectives of this proposal are:

(a) To investigate the resonance interaction of relativistic electrons with EMIC waves on a global scale in order to verify the efficiency of this channel of the RB losses;

(b) To modify our RC/EMIC wave model to include realistic configurations of magnetic and electric fields, and cold plasma electron and ion distributions;

(c) To validate the RC/EMIC wave model using appropriate wave data provided by EMIC wave experimentalists.

Lynn Kistler/University of New Hampshire
Solar Wind Drivers of Plasma Sheet Composition

The goal of this work is to use CLUSTER/CODIF data combined with solar wind and IMF information from ACE to identify the main solar wind drivers that bring ionospheric plasma into the plasma sheet. In the first 4 years of the CLUSTER mission, we have identified 38 storm-time periods when CLUSTER/CODIF was making measurements in the magnetotail region. We have clearly observed that the O+ is higher during storm-times than non-storm times, but the amount of O+ varies considerably from storm to storm. Using solar wind and IMF data, we will identify the solar inputs that result in the most significant ionospheric contribution to the plasma sheet. This project fits directly into the focused topic of determining the effects of ionospheric-magnetospheric plasma redistribution on storms. In particular it will help in the specification and forecasting of the plasma sheet composition, as well as in understanding the energization, transport and loss of ionospheric ions.

James Klimchuk/Naval Research Laboratory
Coronal Heating Origins of the Solar Spectral Irradiance

We will develop a new class of realistic physics-based models of active regions and the global Sun, which will be the predecessors of operational space weather models for predicting the soft X-ray and UV spectral irradiance. Impulsive coronal heating is a fundamental feature of these models. By determining the values of key coronal heating parameters that best reproduce a variety of imaging and irradiance observations, we will gain important physical insights about the nature of the heating mechanism. At the same time, we will continue our detailed investigation of the secondary instability of electric current sheets, which we feel is the most promising of the mechanisms so far proposed. We will perform sophisticated 3D MHD simulations that treat the instability in a far more realistic manner than before. Knowledge gained will be incorporated into the active region and global Sun models to further improve their realism.

Brian Kress/Dartmouth College
Modeling variations in solar energetic particle access to the inner magnetosphere and Earth during geomagnetic storms

The development and validation of a numerical model of solar energetic particle (SEP) access and trapping in the magnetosphere is proposed, to improve predictive capability of SEP fluxes and our understanding of magnetospheric dynamics responsible for variations in SEP fluxes during geomagnetic storms. During severe storms sudden changes in SEP access to Earth are caused both by cutoff variations due to changes in the geomagnetic field configuration and by the transport and heating of ions due to the storm sudden commencement (SSC) inductive electric electric field pulse associated with the impact of an interplanetary shock on the magnetosphere. An accounting for both of these effects is needed to model energetic particle fluxes in the geospace environment. A numerical model that predicts SEP fluxes in the magnetosphere from a given solar wind energetic particle distribution will be developed. The distribution is modeled by following Lorentz and guiding center test particle trajectories in time-dependent fields from a global MHD magnetospheric model, driven at its sunward boundary by measured solar wind parameters. Points in phase space are sampled using test particles weighted by an observed solar wind SEP distribution and retain their weight along particle trajectories. Fluxes predicted by the model will be compared with SAMPEX and HEO spacecraft measurements. The model will be used to improve our understanding of the mechanism(s) responsible for SEP access to low L-shells during storms. The proposed work is submitted under 1.2.2 Independent Investigations in the ROSES 2006 Solicited Research Programs Appendix B, and addresses the NASA LWS TR\&T goal of developing ``the knowledge needed to provide advance warning space environment predictions along the path of robotic and human exploration." and to characterize ``those aspects of the Earth's dynamic environment needed to design reliable electronic subsystems for use in air and space transportation systems."

Robert Leamon/Adnet Systems, Inc.
An Empirical Solar Wind Forecast Model From The Chromosphere

The distinction between the chromosphere, transition region and corona is entirely artificial; the same magnetic field permeates the whole solar atmosphere and heliosphere and as such forms one complex physical system. However, we propose that it is exactly the magnetic field, or, more precisely, the balance of open and closed magnetic structures on local (supergranular, ~20Mm) and global (coronal, >~100Mm) in the photosphere and chromosphere that defines the thermodynamic properties of coronal holes, providing a realistic basis to explore the support and sustenance of the kinetic solar wind. The chromosphere has been largely overlooked as a driving source of the solar wind despite its richness in emission and structure, largely due to the aforementioned complexity. Recently, we [McIntosh and Leamon ApJL, 624, 117, 2005] correlated the inferred topography of the solar chromospheric plasma with in situ solar wind velocity and composition data measured at 1 AU. Specifically, the measured separation in height of the TRACE 1600Å and 1700Å UV band pass filters correlate very strongly with solar wind velocity and inversely with the ratio of ionic oxygen (O7+/O6+) densities. These correlations suggest that the structure of the solar wind is rooted deeper in the solar atmosphere than has been previously considered and form the basis of an empirical solar wind model.

The proposed model provides a near continuous range of solar wind speeds and composition quantities from the structure of the chromosphere and is more precise than the old "fast/ coronal hole or slow/streamer belt" estimate. By means of a coherent, planned and extended observation campaign of the solar chromosphere at disk center, we propose to extend our current results to better understand the nature of the solar wind, its sources and composition. One specific end goal for this three- year pro ject is to develop a (near) real-time solar wind propagation model, with chromospheric topography as input. This useful tool for predictive space weather will have great impact in 2008 when we can replace the intermittent TRACE data with the full-disk, full-time chromospheric topography measurements of the first LWS mission, the Solar Dynamics Observatory.

This proposal addresses Strategic Sub-goal 3B: "Understand the Sun and its effects on Earth and the solar system," specifically NASA Science Outcomes 3B1 and 3B3. However, our improved physical understanding will yield a better observationally driven, physically based ability, to predict space weather on its own and as part of a community based collaborative model within the LWS program.

Charles Lindsey/NorthWest Research Associates, Inc.
Seismic Modeling of Active Regions for Farside Imaging Applications

We propose a theoretical investigation of the basic mechanisms that contribute to seismic signatures of active regions for the purpose of characterizing active regions on the Sun's far surface. The investigation will have two substantial parts: (1) physical modeling of how magnetic fields together with thermal anomalies underlying magnetic photospheres reflect p-modes back into the solar interior, and (2) spherical acoustics of local seismic anomalies based on the results of (1). While this program is basically theoretical, it has immediate applications in a broad range of observational applications. The investigation proposed here is important for recognition of ways to improve of current farside imaging techniques. However, they are even more important, indeed essential, for the development of a useful interpretation of farside signatures with applications outside of helioseismology. Holographic signatures thus far has relied heavily on the relative compactness of active regions and the resulting compactness of their farside signatures. Active regions on the Sun's near surface project a nearside artifact into farside holographic maps. The artifact is so diffuse it does not impair the recognition of individual compact active regions on the Sun's far surface. However, a working assessment of diffuse magnetic regions, which are important for solar irradiance forecasting, for example (see target "d" of the LWS AO), an account of the near-side artifact is essential. Application of standard farside imaging techniques to control simulations representing localized anomalies that can be rotated to any position will accomplish this. The program we propose will be conducted with observational CoIs and collaborators doing closely related empirical modeling applied to near- and far-side seismic signatures computed from both GONG and SOHO/MDI observations. It will also involve collaborators at LASP working on irradiance forecasting and on the SOHO/SWAN project.

Roberto Lionello/Science Applications International Corporation
Physics-based Modeling of Emission in Active Regions

The structure and dynamics of active region magnetic fields play a crucial role in the production of EUV and X-ray emission from the Sun. A key impediment to a more comprehensive understanding and prediction of this emission has been that models of

active region magnetic fields based on real data (e.g., nonlinear force-free models) have largely been disconnected from studies of coronal heating and emission.
Static loop models, the most common method for study emission, have thus far been unsuccessful in explaining some important properties of coronal loops. We propose to use physics-based models of active region magnetic fields that use solar magnetograms as boundary conditions and include realistic energy transport (radiative losses, anisotropic thermal conduction, and coronal heating) in the transition region and corona to investigate emission in active regions.
We will investigate three aspects of active region physics that may lead to time-dependent behavior of the coronal plasma: (1) Thermal non-equilibrium; (2) Non-steady coronal heating; (3) Magnetic field evolution. Preliminary results suggest our model may be capable of explaining some of the mysterious properties of coronal loops. Our model will produce quantitative predictions of emission that we will test against observations from SOHO, TRACE, Yohkoh, and SXI. Our proposed program is also highly relevant to the upcoming Solar-B, STEREO, and SDO missions.

William Lotko/Dartmouth College
Effects of Stormtime Plasma Redistribution on Magnetosphere-Ionosphere Coupling

The Coupled Magnetosphere-Ionosphere-Thermosphere (CMIT) global simulation model will be used to determine how stormtime ionospheric outflows influence 1) the convective transport of ionospheric plasma at auroral and polar latitudes, 2) the distribution and intensity of field-aligned currents at the ionosphere, and 3) the distribution and dynamics of the ionospheric conductivity and Joule dissipation. CMIT integrates the Lyon-Fedder-Mobarry (LFM) global magnetospheric model with the NCAR Thermosphere-Ionosphere Nested Grid (TING) model. This project takes an important step in modeling the magnetospheric and ionospheric-thermospheric regions as a single connected system by including both electrodynamic and inertial couplings between the regions. To this end, we will utilize and advance a recently implemented, multifluid version of the LFM component of CMIT. Proposed extensions to the CMIT model also include causally driven cusp-region, auroral/polar-cap boundary-region, and polar-wind outflows at LFM's ionospheric boundary, regulated by TING's dynamic specification of the ionosphere. This investigation is directly aligned with the goals of LWS TR&T Focused Science Topic b) Effects of Ionospheric-Magnetospheric Plasma Redistribution on Storms. The results will provide a useful touchstone for interpreting measurements, especially mass composition measurements, from existing NASA satellite missions such as Polar and Cluster, and it anticipates future needs to interpret distributed measurements of ionospheric and magnetospheric dynamics from the imminent THEMIS and TWINS missions, the LWS Radiation Belt and IT Storm Probes, and the GEC and MMS satellites.

Glenn Mason/JHU / APL
Understanding Propagation Characteristics of Heavy Ions to Assess the Contribution of Solar Flares to Large SEP Events

Solar Energetic Particle (SEP) events are the most powerful explosions in the solar system, able to create high radiation levels at Earth with little warning. In the large events, particles are known to be accelerated both in the solar flare itself and by the shock driven by the associated Coronal Mass-Ejection (CME). The flare SEPs are known to have a distinct compositional signature including enhancements in electrons, the rare isotope 3He, and the relative abundance of Fe compared to O. Recent observations have shown that these energetic particle signatures of flare particles are often present in events with powerful CMEs along with shock-accelerated particles. This raises the question what are the basic mechanisms responsible for the most intense SEP events? For example: are the SEPs from the flare directly? or are they pre-accelerated at the flare and further energized by the shock? or are remnant suprathermals from previous flares supplying a critical component of the seed population?

The investigation proposed here probes these questions using the heavy ion signature of flare material, namely enhanced Fe/O ratios and their variation with time and energy. We have recently found new evidence that interplanetary scattering plays a critical role in a majority of large western hemisphere SEP events. We describe how to use these observations to provide an observational basis for developing our theoretical understanding of the important role played by particle scattering during large SEP events. Specifically, the observations along with detailed modeling will enable us to place limits on the contributions of particle transport processes to the observed timing and composition in large SEP events. Our proposed study will therefore provide a sound framework for other modelers and TR&T teams to better understand the primary causes of the variability and the temporal evolution of the heavy ion abundances, such as the Fe/O ratio. This, in turn, will allow us to assess the relative contributions of flare particles (either indirectly in the form of seed particles or directly in the form of high-energy particles) to large gradual SEP events observed at 1 AU.

Michael Mendillo/Boston University
Large Scale Variability in Space and Time of Total Electron Content (TEC) Storm-Time Ehancements Driven by Penetration Electric Fields.

The largest changes in the terrestrial ionosphere occur during geomagnetic storms. During such events, electric fields of magnetospheric origin penetrate to middle and low latitudes; Joule heating and particle precipitation cause expansion, winds and composition changes in the thermosphere. The entire ionosphere, as portrayed in the parameter Total Electron Content (TEC), can be enhanced to levels far above pre-storm values, conditions that have major consequences on GPS navigation systems now used widely (particularly in FAA systems). Examples of storm enhanced densities (SEDs) have been portrayed using GPS diagnostics during several remarkable events, termed super-storms, during the current solar cycle. Ongoing studies are needed to track such effects as a function of season and phase of the solar cycle in order to characterize the

variabilities in the gradient scenarios. Most of the events examined to date single out the American longitude section near 70 W for maximum effects, due to the dominance of electrodynamics in this region of maximum dipole tilt.
While the physics of the negative phase is well known (enhanced loss rates), virtually no attention has been given to the negative phase as a source of severe spatial gradients, and thus of equal importance to those associated with SEDs. Here we propose a study of TEC during 180 geomagnetic storms observed during a previous solar cycle (#20) spanning the years 1967-1978. This unique database comes from Faraday rotation measurements of radiobeacon signals from geostationary satellites using the AFCRL network of stations from Greenland to the Caribbean. Using data from this crucial longitude sector, we propose a comprehensive study of both sources of TEC gradients and their variability's with season, solar cycle, and severity of the geomagnetic storm. The TEC data in question exist in fully reduced form in a series of unpublished research reports funded by the Air Force. The PI was co-author on all three of these reports and thus they are fully available for research and applications to current space weather issues.
A prediction scheme for the types of ionospheric positive phase storm possibilities (prompt dusk effects vs. delayed or absent ones) was proposed decades ago using a small sample of these earlier datasets, but never fully tested with later data. We propose to do that now. Finally, to understand the nature of large TEC gradients at the "special" longitudes of dipole tilt in the North American sector, we will conduct a companion study using ionosonde data from Hobart, Tasmania, where the sub-auroral conditions comparable to those at 70 W occur in the southern hemisphere.
A small PI-led team can address these major issues of direct relevance to LWS research targets due to the readily available dataset and demonstrated expertise in storm studies.

Christopher Mertens/NASA Langley Research Center
Empirical Ionospheric E-Region Solar-Geomagnetic Storm Correction to the IRI Model Using TIMED/SABER Data

We propose to develop an empirical ionospheric E-region storm-time correction to the International Reference Ionosphere (IRI) model. Observations from the Sounding of the Atmosphere using Broadband Emission Radiometry (SABER) instrument onboard the Thermosphere-Ionosphere-Mesosphere Energetics and Dynamics (TIMED) satellite will be used to correct the E-region IRI NO+ and electron densities for solar-geomagnetic activity. The objective of this proposal will be achieved in two steps: (1) derive a parameterization of the E-region response to solar-geomagnetic storms as a function of integral ap-index, and (2) validate the proposed storm model by comparisons with SABER-derived NO+(v) volume emission rates (VER), incoherent scatter radar measurements, and results from the Ionospheric Model for Auroral Zone (IMAZ). The proxy used to develop the storm model is SABER-derived profiles of NO+(v) VER. NO+(v) VER during all magnetically disturbed periods contained in the SABER database from 2002-2006, for example the April 2002 and October-November 2003 storm periods, will be used to develop the storm model parameterization using linear impulse-response theory. The NO+(v) VER will be retrieved from SABER 4.3 um limb emission measurements by (1) removing the background contribution from CO2 infrared emission, and (2) by performing a standard Abel inversion on the residual radiance to obtain the vertical profiles of NO+(v) VER. The latitude range of the storm model extends from the polar region to mid- to low-latitudes. The magnetic local time coverage is in the dawn to dusk sector. The altitude range is roughly 90 km to 180 km. The empirical storm model is independent of NO+ or electron density profile shapes, and independent of chemistry, kinetics, or spectroscopic parameters. Our storm model will help accurately specify the lower ionosphere during solar-geomagnetic disturbances for all space technologies that use radio wave propagation through the ionosphere. This work is proposed in support of the LWS Tools and Methods component of the Targeted Investigations Program, which also suports NASA's Strategic Objective (15).

Thomas Moore/NASA Goddard Space Flight Center
Storm-Time Plasma Redistribution Processes and Consequences

Objectives:
We propose to establish how ionospheric plasma expansion into the magnetosphere during storms changes as a result of storm energy flows, and how this expansion influences the dynamics and coupling of the magnetosphere and ionosphere. Emphasis will be on the plasma and geomagnetic field conditions of the inner magnetosphere, as distorted by the ring current, with the evolution of the ionospheric conductance, temperature and densities. Measures of success include the identification of principal mechanistic features and quantitative assessment of their impacts over the range of storm-time conditions and their solar wind and IMF drivers.
Our specific objectives are to:
i) assimilate published observations into a developing model;
ii) assess and simulate the entry and circulation of solar wind plasmas.
iii) specify and forecast plasmasheet and ring current composition, energy and spatial distribution;
iv) assess the impacts of storm-time redistribution on magnetosphere-ionosphere coupling.

Methods and Techniques:
The proposed funding will support a team effort including theoretical analysis, assimilation of observational results including empirical-statistical models based on both space borne and ground based data sets, and global modeling of the ionosphere and magnetosphere. We will investigate the ionospheric processes relevant to its expansion into the magnetosphere, and the influence of specific physical phenomena, using published ionospheric models. We will investigate the consequences and impacts of magnetospheric intake of gas and plasma from all sources. We will use all relevant data sets from of the Heliophysics Great Observatory to determine the dynamic local response of the source regions to solar wind influences. Empirical specifications will improve and validate ionosphere-thermosphere, neutral solar wind, and heliospheric gas models, leading the way toward the integration of such models within global circulation models of geospace and its response to the heliosphere.

Significance:

Large-scale redistribution and restructuring of the ionosphere by storm-induced currents and electric fields produces massive ion flows into the magnetosphere. An enhanced polar wind, heavy-ion auroral wind from the low-altitude cusp and auroral regions, and convective entrainment of an eroding plasmasphere are all consequences of large-scale ionospheric changes that are especially prevalent during intense storms. Entrained ionospheric plasmas populate the plasmasheet and ring current, modify magnetospheric convection and current systems, and, thereby couple back into ionospheric plasma electrodynamics. Quantitative understanding of the effects of storm-time ionospheric restructuring on the magnetosphere, and how this feedback evolves with time, is essential to develop forecast-quality models of near-Earth space weather.

Dibyendu Nandi/Montana State University
Magnetic Origins of Solar Irradiance Variations

We propose to explore the magnetic origins of solar spectral and total irradiance variations, through observations, data analysis and modeling approaches to directly address NASA-LWS TR&T Program's Focused Science Topic "d) Solar Origins of Irradiance Variations" as stated in this NRA. Changes in the spectrally integrated total solar irradiance (TSI) affect global climate directly, since TSI is the primary source of radiative energy input to the Earth system. Indirect climate influences include the solar radiative output at different wavelengths (spectral irradiance), which affect specific components of Earth's atmosphere in diverse ways. Exploring the nature and physical basis of this solar radiative forcing is vital towards understanding and predicting its effect on life and society, and for clearly distinguishing the natural and anthropogenic causes of global climate change.

Solar spectral and total irradiance variability is governed by the changing magnetism of the Sun. Specifically, the appearance, evolution and associated dynamics of solar active region magnetic fields and its overlying coronal loops, directly contribute to irradiance variations - the latter is clearly magnetic in origin. In this proposal we plan to explore the magnetic origins of solar irradiance variations by: I) Establishing the relationship between important active region magnetic parameters (such as field strength, flux, loop length, measures of non-potentiality) derived from magnetograms and the observed solar spectral and total irradiance, II) Studying the connection between active region evolution and irradiance variations through the usage of a magnetogram partitioning algorithm that can follow the fragmentation of a decaying active region and the consequent redistribution of flux between the main spot and fragmented regions, III) Modeling the observed dependence through analytic and numerical techniques to develop predictive capabilities for solar irradiance variations. Through specific examples, we demonstrate that the proposed data analysis and modeling are feasible and the probability of success in the proposed research is high. The research experience of the proposal team encompasses solar vector magnetic field analysis, coronal imaging, and data analysis and modeling of spectral irradiance variations.

This proposal is highly relevant for the LWS TR&T program's focused research topic "d) Solar origins of Irradiance variations" as stated in this NRA. Our proposal also addresses the LWS program's general objective to understand the solar origins of Space Weather and Climate and develop predictive capabilities to mitigate their adverse effects on life and society. In the larger context, our proposal supports NASA Science Mission Directorate's strategic sub-goal 3-B - "Understand the Sun and its effects on Earth and the solar system".

Nariaki Nitta/Lockheed Martin Advanced Technology Center
Solar Flares as a Source of Gradual Solar Energetic Particle Events

We propose a multi-disciplined study of the origin of gradual solar energetic particle (SEP) events with detectable >50 MeV protons, focusing on how the variability of SEP properties is accounted for by the conditions or properties of the associated solar flares and coronal mass ejections. Many gradual SEP events have been shown to exhibit the properties close to those of impulsive SEP events, such as elevated Fe/O ratios and high heavy ion charge state. We examine low coronal images and white-light coronagraph images to identify any special conditions of the flares associated with Fe-rich SEP events, and combine these results with detailed timing analysis of radio signatures, to find out when and where particles are accelerated and released to the interplanetary medium. The importance of how accelerated particles access open field lines that intersect spacecraft should not be neglected even in the context of gradual SEP events. This will be addressed by characterizing the magnetic field topology in and around the flaring regions, including the evaluation of magnetic field extrapolations. Using extrapolated coronal magnetic fields combined with CME geometrical and kinematical parameters, we will test the hypothesis that the angle between the magnetic field and the normal of the CME-driven shock may affect the observed SEP properties. The remote sensing observations and magnetic field modeling will be compared with SEP properties at >25 MeV/nuc including spectra and abundance for heavy ions as well as high-energy protons and electrons. The temporal variation of these properties will be a key aspect of the analysis. The proposed study directly responds to the LWS TR&T Focused Science Topic ``Understanding how flares accelerate particles near the Sun and how they contribute to large SEP events." This investigation will also advance our understanding of the origin of CMEs.

Judit Pap/University of Maryland Baltimore County
The Fine Structure of Active Regions and Weak Magnetic Fields from MDI Images

In response to NASA Roses 2006 B.7 - Living With a Star Targeted Research and Technology Program (NNH06ZDA001N-LWS), we submit this proposal entitled "The Fine Structure of Active Regions and Weak Magnetic Fields from MDI Images" under the Focused Science Topic: "Solar Origins of Irradiance Variations". The goal of the proposed research is to carry out a detailed study of solar spectral irradiance variations from UV to the infrared wavelengths and to compare the measured spectral irradiance changes to the observed variations in total solar and spectral irradiances. The proposed investigation will focus on the following three major science questions: (1) How does the formation and evolution of sunspots and active regions influence spectral irradiance variations; (2) what is the energy budget of solar active regions; and (3) how to detect and characterize the weak magnetic fields outside of active regions? The proposed research will directly address one of the Focused Science Topics: namely, our research will study in detail the magnetic topology of active regions and their role in irradiance changes to better understand the physical processes by which solar magnetic activity causes these variations. To achieve our goals, we will use the full disk and high resolution MDI images. Solar spectral irradiance to be used in this study will come from the SORCE/SIM experiment and also from the UARS/SUSIM and SOLSTICE experiments at UV wavelengths. Total solar irradiance is provided by the SOHO/VIRGO, ACRIMIII and SORCE/TIM experiments. As part of the proposed work, we will also develop a new method to identify the quiet-Sun values and to separate them from the weak magnetic field structures. The proposed work will enhance current MDI image analysis techniques and it will also provide technical and science tools to the SDO/HMI experiment. The proposed work is a three years long effort. The proposed team (Dr. Judit M. Pap, Principal Investigator; Dr.W. Dean Pesnell, Co-Investigator, and Professor Roger Ulrich, Collaborator) is highly experienced in image analysis as well as studying and interpreting irradiance variations.

Robert Pfaff/NASA Goddard Space Flight Center
An investigation of the highly structured topside ionosphere at mid- and low-latitudes and its dependence on magnetic storms as observed with the DEMETER and DMSP satellites

This investigation will explore the plasma structure and irregularities in the topside ionosphere (660-830 km altitude) at mid- and low-latitudes using data from the DEMETER and DMSP satellites. We will examine the ion drifts, plasma density and temperature, electric field and plasma density irregularities, and in some cases, the magnetic field irregularities that characterize the unstable, topside ionosphere. A chief goal of the investigation is to determine how this structure depends on magnetic storms and penetration electric fields. The mid-latitude irregularities are compared with those associated with equatorial spread-F as well as with the intense irregularities associated with the trough region that are observed at sub-auroral latitudes during geomagnetic storm periods. The observations will be related to theories of mid-latitude, topside plasma density structuring during magnetic storms. This research is highly germane to NASA's interest to understand the geospace environment and to space weather effects regarding disruption of communication and navigation signals in the near-space environment.

Ilia Roussev/University of Hawaii
LWS Support for SPD Summer School on Observations and Models of the Solar Corona in 2007

We propose to organize the third SPD summer school on the island of Maui, Hawaii, in the summer of 2007. The school will take place at the new Advanced Technology and Research Center of the Institute for Astronomy. In addition, we will take advantage of the nearby Haleakala Solar Observatories (Mees and SOLARC) and the Maui High

Performance Computing Center. The summer school will benefit from the expanding solar research and education programs at the IfA, which span both observational and computational solar physics. The summer school will be scheduled to either precede or follow the 2007 SPD meeting, which will take place in Honolulu, Hawaii, during the period May 24-31. The proposed school will educate graduate students about the present knowledge of the corona both in the Sun and other stars as achieved through both observations and theoretical-numerical modeling. We will prepare students for the future capabilities of ATST, Solar-B, and STEREO. Our goal is to use ground-based observatories and NASA missions to inspire and motivate our students, as well as to educate them about the Sun and its dynamic processes that affect the Earth, life, and society.

Philip Scherrer/HEPL/Stanford University
Detection of Emerging Active Regions and Forecast of Their Evolution and Activity by Time-Distance Helioseismology.

We propose to develop time-distance helioseismology techniques for the application of detecting emerging active regions before they become visible. Techniques will also be developed for predicting active region growth, decay and maximum activity stage. The work will include development of deep-focus time-distance data analysis methods for imaging weak and rapidly evolving sound-speed structures and mass flows associated with new emerging magnetic flux in the convection zone, monitoring and predicting the growth and complexity of the subsurface structures, and also a search for the deep nests of long-living complexes of activity ("active longitudes") and their relationship to the global circulation of the Sun. An important goal of this investigation is to develop and deliver software for deep-focus time-distance analysis and inversions of Solar-B and SDO data.

Gerald Share/University of Maryland
Comparison of Accelerated Particle Populations at 1 AU and at the Sun

We propose to study the flare-accelerated particle population at the Sun using gamma-ray observations from RHESSI, Yohkoh, CGRO, and SMM. These can be compared to particle-acceleration models and to particle measurements in space and at Earth. This is a key element in determining the contribution of flare-accelerated particles to large gradual SEP events, a goal of the LWS-TR&T in preparing for the Sentinels Mission. As an example of this study we discuss a recent RHESSI analysis of the 2005 January 20 event that revealed two distinct accelerated-particle components at the Sun: 1) an 'impulsive' release lasting ~10 minutes with a power-law index of ~3 observed in a compact region on the Sun and 2) an associated release of much higher energy particles with index <2.3 interacting at the Sun for about two hours. The spectrum of the latter component is consistent with that measured in space. A similar study can be performed in any of over fifty jointly observed gamma-ray flares and SEP events. We suggest that emphasis be placed on the most energetic of these events, those that produce Ground Level Events (GLE).

Edward Sittler/NASA Goddard Space Flight Center
Empirical Determination of Effective Heat Flux and Temperature using Semi-Empirical 2D MHD Model of the Solar Corona and the Solar Wind

Under the LWS TR&T "Tools and Methods" section, we are proposing to develop empirical models of the effective heat flux and temperature (wave pressure terms) using our semi-empirical modeling of the Sun's corona at both the MHD level and the kinetic level. Our empirical estimates of the effective heat flux and temperature would replace the ad hoc functions now used in present funded 3D modeling efforts of the Sun's corona and solar wind. At present this modeling has concentrated its efforts on the Sun's corona during solar minimum when the corona and solar wind are relatively simple to model, azimuthal symmetry is a good approximation and the corona is in a quasi-steady state configuration. This modeling effort has been focused around the semi-empirical model originally presented by Sittler and Guhathakurta (1999a, 2002) and more recently by Guhathakurta, Sittler and Ofman (2006). Our modeling effort would use SOHO, Ulysses, WIND and ACE observations, and incorporate the usage of magnetogram data to improve the fidelity of our magnetic field model. The effort is presently 2D MHD and steady state and we will eventually generalize to 3D. During solar maximum the boundary conditions are more complex and will require observations of sufficient precision that may not be available at this time. STEREO, Solar-B and SDO may allow this to be done with some success. Present 3D MHD codes are unable to provide realistic solutions of the coronal plasma and magnetic field without resorting to ad-hoc source terms in the momentum, and energy equations. It is our scientific opinion that such approach is flawed, and the empirically determined wave pressure terms and heat input terms of the proposed study would provide more realistic solutions.

Stanley Solomon/University Corporation for Atmospheric Research
NASA Living With a Star Workshop

We request support for the organization of a Living With a Star scientific workshop that will focus on the magnetic couplings and plasma interactions from the solar interior to interplanetary space, on solar irradiance variations, and on geospace and atmospheric scientific topics relevant to the LWS program. The meeting will be hosted by the NCAR High Altitude Observatory in Boulder, Colorado in the fall of 2007. It is expected to bring together approximately 300 active scientists and students from all branches of Heliophysics. This meeting comes at a time when the first strategic LWS mission, SDO, is only a year from launch, when Solar-B and STEREO will have been observing the Sun and heliosphere for several months, and while many other NASA missions continue to provide a Great Observatory view of the Sun, heliosphere, and geospace. The Scientific Organizing Committee will include scientists from the SDO, STEREO, and Solar-B missions, representatives of the currently active Heliophysics Great Observatory fleet, heliospheric and geospace scientists, and NASA/HQ representation from the LWS executive. The Local Organizing Committee will include scientists and support personnel from the High Altitude Observatory and other scientific organizations in

Boulder. Administration and management of the meeting will be performed by the UCAR Visiting Scientist Program under the direction of the Local Organizing Committee. The requested funds will be used mainly for student support, coordination and managment of student support, and to lower the registration fee for all participants by covering some of the logistical costs.

Robert Stein/Michigan State University
Applying Magneto-Convection Simulations to Helioseismology and Flux Emergence

The goal of this research is to test and refine techniques for detecting active regions before the are visible and to investigate the physical process of flux emergence through the solar surface (focused science topic 3). To achieve this we will perform realistic, three-dimensional, magneto-convection simulations of a region of the solar surface larger than supergranules (96 Mm wide by 30 Mm deep) for three different situations:

(1) Magneto-convection with an active region
(2) Magneto-convection with horizontal field advected into the domain by inflows at the bottom
(3) The rise of a magnetic flux tube from near the bottom through the surface.

The data sets produced by these simulations are of large enough dimensions and will be of long enough duration (more than two days) that they will provide a test bed for evaluating and refining local helioseismic techniques -- time-distance, ring diagrams and holography. This will improve our ability to predict the emergence of magnetic flux before it becomes visible and to study the structure and evolution of active regions.

Robert Strangeway/University of California, Los Angeles
Ionospheric Plasma Outflow Scaling Laws as a Function of Solar Cycle

The polar and auroral ionosphere are a signficant source of plasma for the magnetosphere. This plasma can be source for the plasmasheet and ring current, and can also affect the dynamical response of the magnetosphere through mass loading of the tail lobes and plasmasheet. Thus understanding the variability of ionospheric outflows is essential in specifying the response of the magnetosphere to changes in the solar wind drivers. We have recently derived scaling laws that specify ionospheric outflow fluxes as a function of electromagnetic and electron energy fluxes to the polar and auroral ionosphere. These scaling laws were determined from a 3-day interval of data from the Fast Auroral Snapshot Small Explorer. We will extend the scaling laws to the full solar cycle, and further use computer simulations such as those provided by NASA's Community Coordinated Modeling Center (CCMC) to investigate the impact of solar illumination on the flux of ionospheric plasma that flows into the magnetosphere.

Allan Tylka/US Naval Research Laboratory
The Disappearance of Large, Fe-Rich Solar Energetic Particle Events in the Declining Phase of Cycle 23: Implications for the Role of Flares

A large body of observations in the 1980s led to the formulation of a "standard model", by which solar energetic particle (SEP) events are divided into two categories, "gradual" and "impulsive". These names are short-hand for the likely sites and mechanisms of particle acceleration. Gradual events are those in which a preponderance of evidence points to acceleration at shocks driven by fast coronal mass ejections (CMEs). Impulsive events, on the other hand, are generally ascribed to particle acceleration at sites associated with flares, probably through resonant wave-particle interactions following magnetic reconnection. One of the defining distinctions between the two event categories is the event-integrated Fe/O ratio, with gradual events at a few MeV/nucleon exhibiting typical coronal values while impulsive events generally show strong enhancements. But the precise, comprehensive observations from a fleet of new spacecraft at the start of Cycle 23 immediately challenged this neat picture: Fe/O ratios generally varied with energy, and a large fraction of the nominally "gradual" events, when observed at energies above the few MeV/nucleon where the two categories had originally been developed, showed enhanced Fe/O ratios approaching those typically associated with impulsive events. In 1997-2002, 13 out of the 38 very large SEP events (identified by >30 MeV proton fluence above 2 x 10^5/cm^2-sr) had an Fe/O ratio above 30 MeV/nucleon that was at least four times the nominal coronal value. But in 2003-2005, zero out of the 20 events satisfying the same selection criterion displayed comparably large Fe/O enhancements. This dramatic shift clearly indicates that the condition(s) that allow flares to contribute to large SEP events have changed in some fundamental way in the declining phase of Cycle 23. Identifying the factors behind this shift is the focus of this proposal, which is submitted in response to LWS TR&T Focused Research Topic T3.e. In particular, several hypotheses have been developed in recent years in order to explain the flare-like composition seen at high energies in some large gradual events. For each of the pending hypotheses, one can draw inferences about how they would accommodate the late-Cycle disappearance of Fe-rich events. We propose to use flare, CME, radio, and SEP observations to investigate each of these inferences, in hopes of narrowing the field of viable hypotheses. Our work will thereby sharpen the objectives for future SEP studies by STEREO and Sentinels. In particular, this proposal will help to clarify the range of possible factors that drive the SEP origin in individual events, and thereby contribute to refining requirements and observation strategies for the Sentinels. This proposal addresses NASA Strategic Sub-Goals 3B.1, 3B.2, 3B.3, and 3C.4.

Jie Zhang/George Mason University
Developing Tools of Automatic Coronal Mass Ejection Detection and Characterization.

The objective of this proposal is to develop a software package to automatically detect, characterize and catalog corona mass ejections (CMEs) using coronagraph imaging observations. The package provides the following specific functionalities: (1) CME initial detection, using image processing methods based on thresholding, histogram analysis and morphological analysis. (2) CME tracking and characterization based on a continuous sequence of images, taking advantage of the coherent nature of CME movement. (3) CME event classification using various existing data mining methods based on the large number of parameters generated. (4) generation of an accurate and complete CME catalog. (5) developing a near-real time detection and warning module for space weather forecasting. The automated method is far more efficient than the human manual inspection method. The automated method also extracts a large number of meaningful parameters for scientific research, free of human bias. The proposed software package will be developed based on ongoing SOHO/LASCO C2 data, and will be applied to the upcoming STEREO/SECCHI data. We will test and validate the tool package with the manual-based CDAW catalog and the existing CACTUS automated catalog. Comparing with the existing catalogs, our catalog will be much more comprehensive in terms of number and accuracy of the parameters. The proposed near-real-time module will be timely, which is critical for space weather applications. The package will be developed with the IDL programming language.

CMEs are the main drivers of particle storms, geomagnetic storms and other severe space weather phenomena. The timely detection and complete catalog of CMEs serve many purposes of the LWS programs. The amount of data available becomes overwhelming. There is a strong need to automate the event detection and classification processes. The proposed methodology helps convert NASA mission data into scientific information quicker and better, or otherwise can not be obtained. Hidden scientific facts could be found through mining the large parameter space produced by automatic means. Therefore, this project will increase the scientific productivity of the SMD research endeavors from present and future NASA missions. This project will be carried out through an inter-discipline effort among experts in computer science and solar physics at George Mason University, through collaboration with the Naval Research Lab. A large part of the funding will be used to support a graduate student working toward his Ph.D. dissertation. This project directly addresses the NASA strategic sub-goal 3B and is highly relevant to the strategic sub-goals 3C. If awarded, we plan to organize a summer school addressing the LWS data environment as an E/PO effort.