Living W/a Star Targeted Rsrch & Tech: NASA/NSF Partnership for Collaborative Space Weather Modeling
Abstracts of selected proposals.
(NNH05ZDA001N-LWS2)

Below are the abstracts of proposals selected for funding for the Living W/a Star Targeted Rsrch & Tech: NASA/NSF Partnership for Collaborative Space Weather Modeling Program. Principal Investigator (PI) name, institution, and proposal title are also included.

Tamas Gombosi / University of Michigan
The Comprehensive Corona and Heliosphere Model (CCHM)

A primary goal of the NSWP and the LWS program is the development of first-principles-based models for the coupled Sun-Earth system by the early 2010s. We propose to develop and maintain a first-principles based comprehensive numerical model of the 3D time-dependent structure and dynamics of the slowly varying corona and the ambient solar wind. The model will be based on the Space Weather Modeling Framework, a high-performance, flexible, easy-to-use computational tool developed at the University of Michigan. The proposed CCHM will be developed on the timeline described in the NSWP Implementation Plan. We will deliver all expected and desired features of the time-dependent corona and heliosphere model described in Section 1.2.2 of the Strategic Capabilities NRA. We will work with CCMC, NOAA SEC, and the solar-heliospheric community to expand the available physics models, assist the community in usage of the new capability, validate the individual models and calculate skill scores. The main features of the model will be: (i) a 3D quantitative description of the large scale structure and properties of the corona and the heliosphere at any given instant in time; (ii) the incorporation presently available and forthcoming line-of-sight photospheric magnetic field data, as well as vector magnetic field observations as input; (iii) the ability to initiate simple transients, as well as sophisticated magnetically driven solar eruptions; (iv) predictions of time dependent solar wind parameters at a point or an object (Earth, Mars, spacecraft) in space including the energetic particle environment; (v) sufficient modularity to incorporate routines containing new or more sophisticated physics; (vi) a user-friendly web portal to create, submit, monitor and analyze runs (including graphics) by the general research community; (vii) faster than real-time capability on reasonable computational resources, yielding the flexibility for quick-turn-around runs; (viii) the ability to run continuously in a ¿pipeline mode¿ and describe the continuous topological changes of the solar magnetic field (this requires that continuous data streams from SoHO/MDI, SOLIS, and later on from SDO/HMI, be available). We will deliver a working version to the CCMC and/or other centers in the first half of the funding period. We will apply rigorous evaluation and validation procedures throughout the project.

Jon Linker / SAIC
A Next-Generation Model of the Corona and Solar Wind

The ambient structure of the solar corona and inner heliosphere plays a crucial role in the goals of Sun-Earth Connection science, yet both remote solar and in situ observations severely under-sample this region. Three-dimensional, time-dependent models have recently advanced sufficiently to provide a meaningful context for interpreting and connecting these disparate observations. We propose a strategic capability to combine the most sophisticated of these models with the latest techniques for deriving time-dependent photospheric magnetic field data and deliver a GUI-driven model that will be of broad appeal to the solar and heliospheric scientific community. This model will encapsulate both our current technical capabilities as well as a number of important improvements that will be developed and incorporated during the course of this work. The observed photospheric magnetic field acts as the primary boundary condition to the models and we have found that the solar wind solution is strongly dependent on it. Thus our proposed work includes detailed studies to improve the quality of this input. Moreover, we will drive the model with time-dependent output from flux transport codes, allowing us to produce a real-time model of the solar wind, which would be delivered to the CCMC. Ultimately, it might replace the current WSA model at the National Weather Service's Space Environment Center. Global MHD models are, by necessity, complex. In the past, typically only code developers were able to successfully run their code. We propose to abstract away the unnecessary complexities by providing a uniform GUI interface with which to initiate runs. We will also provide a set of GUI tools for post-processing, analysis, and visualization. Much of this work has already been done as part of previous and ongoing programs. Our team includes experts in the range of disciplines required to successfully carry out this project, including solar magnetometry, surface flux evolution modeling, coronal and solar wind modeling, and computational physics.

Joachim Raeder / University of New Hampshire
Development and Validation of a Comprehensive Magnetosphere Ionosphere Model

We propose a 5 year effort to combine a number of existing models of Earth's magnetosphere, ionosphere, and thermosphere into a comprehensive geospace model (CGM). Specifically, the CGM will be comprised of the OpenGGCM magnetosphere model, the CTIPe thermosphere-ionosphere-plasmasphere model, the CRCM and the RCM ring current models, and the Fok RBM radiation belt model. A substantial part of this effort is devoted to verification and validation of the CGM. We will use a number of ground and space based data sets to establish metrics and skill scores. The CGM will be able to perform in real time and will be run for at least one month in real time mode for verification. At the end of this effort we will deliver the CGM to the Community Coordinated Modeling Center, which may then further test it and prepare for transition into operations. The model will have the capability to follow the geospace response to time-dependent variations in the forcing from the solar wind and interplanetary magnetic field. The model will predict the following space weather effects: magnetospheric convection and auroral precipitation responsible for electrojet currents, radiation belt electron and ion fluxes, sub-auroral polarization streams and their impact on plasma density at mid-latitude, mid and low latitude plasma restructuring by the interaction between the penetration and dynamo electric fields, the background neutral, plasma, and electrodynamic context for forecasting irregularities, and thermospheric neutral density responsible for satellite drag, and O/N2 ratio, which is important for ionospheric production and loss rates. CGM will contribute many important new and unique aspects to the modeling and characterization of the Geospace domain. In particular, the development of a unified potential solver coupling the electrodynamics components will accommodate both symmetric and asymmetric elements of the inter-hemispheric interactions. CGM will also have a realistic topside ionosphere and plasmasphere, which is essential for the correct treatment of plasma redistribution at mid and low latitudes, and the emptying and refilling of the plasmasphere. It will have the potential to respond to realistic dynamical forcing from the lower atmosphere, which is responsible for much of the eomagnetically quiet day-to-day variability. The radiation belt module will also have the capability to respond to time-dependent magnetic and electric fields and covers both ions and electrons over the entire relevant energy range. CGM will address all the expected features of the development of the comprehensive magnetospheric-ionospheric-thermospheric model. In addition, the model will assimilate data for ionospheric and magnetospheric convection, include multiple species in the plasmasphere and the magnetosphere, and will accomodate multiple solar wind and interplanetary magnetic field monitors.

Aaron Ridley / University of Michigan
The Community-based Whole Magnetosphere Model

We propose to build a Community-based Whole Magnetosphere Model (CWMM). This model will be comprised of seven phyiscs domains: global magnetosphere, inner magnetosphere drift physics, radiation belts, plasmasphere, polar wind, ionospheric electrodynamics, and upper atmosphere and ionosphere. The models will be self-consistently coupled together with the only drivers being the solar wind and interplanetary magnetic field, the solar EUV, and the forcing from the mesosphere. The different domains will be coupled together using the Space Weather Modeling Framework (SWMF). The CWMM will be released to the Community Coordinated Modeling Center (CCMC) and the source code and all documentation will be made publically available. At present, we have coupled together five of these domains and have proven that they can be driven as a self-consistent system using only upstream solar wind, IMF, and solar EUV conditions. We have shown that this coupled model handles some of the strongest storms ever experienced (e.g. the October 29-30, 2003 storm), reproduces data in the thermosphere, ionosphere, and magnetosphere. The current version of the SWMF is under evaluation at the CCMC and limited runs on request are being offered. We propose to create the CWMM by including more models of the geospace region, and by concentrating on the rigorous validation of the coupled system of models. The CWMM will consist of 15 community created models of the magnetosphere, ionosphere, and thermosphere and will be made available back to the community for their use through runs on request from the CCMC and source code from the University of Michigan. Many of the models that will be included in the CWMM have been individually validated, but it is our goal to validated the coupled model as a whole, and quantify the improvement in the performace as more physics-specific models are included. This will be done through the use of community established metrics such as drift-meter measurements, total electron content measurements, and radiation belt fluxes. The CWMM will have the ability to both assimilate data within the ionosphere and magnetosphere, and output results at precise satellite measurement locations for rapid assessment of model quality. These features will be made available to the general community through a real-time operational model interface at the University of Michigan.

Nathan Schwadron / Boston University
Earth-Moon-Mars Radiation Exposure Module (EMMREM)

We are preparing to return humans to the Moon and setting the stage for exploration to Mars and beyond. However, it is unclear if long missions outside of Low-Earth Orbit (LEO) can be accomplished with acceptable risk. The central objective of our project, the Earth-Moon-Mars Radiation Exposure Module (EMMREM), is to develop and validate a numerical module for completely characterizing time-dependent radiation exposure in the Earth-Moon-Mars and Interplanetary space environments. EMMREM provides the ability to predict radiation exposure anywhere on the surface or atmosphere of Earth, on the Moon, Mars, and in interplanetary space between Earth and Mars. EMMREM is designed for broad use by researchers to predict radiation exposure generated by almost any particle distribution incident from interplanetary space. EMMREM is developed using contemporary, state-of-the-art, physics-based particle radiation models. Beyond this, it has the capability to incorporate new models, as they become available, to give continually improved estimates of radiation hazards and effects. EMMREM is comprehensively validated in the environments where risks need to be assessed, using direct and contemporaneous measurements near Earth, at the Moon and Mars to significantly reduce uncertainties in radiation exposure. EMMREM characterizes the extremes, statistics, and variations over time of radiation exposure caused by solar energetic particles and cosmic rays. The results of EMMREM will improve risk assessment models so that future human exploration missions can be adequately planned. This makes EMMREM highly relevant to NASA's Vision for Space Exploration and Living With a Star Programs. EMMREM's highly cross-disciplinary team makes the unprecedented link from particle radiation researchers to radiation biophysics researchers and risk assessment specialists. EMMREM is a powerful tool, urgently needed to reduce uncertainties in risk assessment models. EMMREM is the missing link from Space Science to Space Exploration. EMMREM's central objective is achieved through four primary activities: 1. We develop the central EMMREM module for predicting time-dependent radiation exposure (Linear-Energy-Transfer spectra and dose-related quantities) based on existing, well-established, working codes including the BRYNTRN and HZETRN code developed at NASA Langley and the HETC-HEDS Monte Carlo code developed at Oak Ridge National Laboratory and the University of Tennessee. 2. We develop interfaces between EMMREM and energetic particle simulations using, as a test-bed, sophisticated, physics-based solar energetic particle (SEP) and cosmic ray models. Simulations and associated EMMREM radiation exposure predictions are used to characterize typical, and worst-case event scenarios, and to characterize exposure near-

Earth, at the Moon, Mars and throughout the inner heliosphere over the solar cycle. 3. We develop interfaces between EMMREM and direct observations of particle radiation (SoHO, ACE, Wind, STEREO, SAMPEX, NOAA-GOES and Ulysses). The observations are used both to validate SEP and cosmic ray simulations, and as direct input to predict radiation exposure at the Earth, on the Moon, Mars and in interplanetary space environments. 4. We significantly reduce radiation exposure uncertainties through comprehensive validation in the Earth, Moon, Mars and interplanetary space environments. EMMREM is validated with previously measured LET spectra from the International Space Station (ISS) and the Space Shuttle, observations from LRO/CRaTER, MSL/RAD, MARIE on Mars Odyssey, and using an extensive database of Accelerator Beam Measurements.

Leonard Strachan / Smithsonian Astrophysical Observatory
Quantitative Validation and Assessments of Solar/Heliospheric 3D Model Codes Using Empirical Data from Remote-Sensing and In Situ Measurements

We propose to use current and future MHD codes to construct 3D time-dependent models of the coupled Sun/heliosphere system for specific time intervals. Observations from SOHO, ACE,WIND, Ulysses and other solar/heliospheric missions will be used as benchmarks to test the model results. We will work with the developers of the 3D MHD codes to produce test metrics that will provide an independent and quantitative assessment. The models, test results and related software tools will be shared with the code developers and other researchers.