# NASA Living with a Star (LWS)
# Targeted Research and Technology (TR&T)
# Steering Committee Report for 2006-07

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This document reports the deliberations of the FY07 NASA LWS TR&T Steering Committee (TSC). The TSC held a teleconference and two 'in person' meetings, February 12-13, 2007 (Greenbelt, MD) and April 23-24, 2007 (Boulder, CO). In addition to the Steering Committee members listed above Lika Guhathakurta (LWS Lead Program Scientist) and Mona Kessel (LWS Deputy Program Scientists) were present at all telecons/meetings. David Byers (AFOSR), Joe Gurman (GSFC) and Karel Schrijver (Lockheed) also participated in the work of the TSC.

Most of the deliberations concerned three topics:

- The decadal strategic plan for the LWS TR&T program,
- The determination of *focused science topics* for FY08
- The determination of *strategic capabilities* for FY08.

## 1 Decadal Strategic Plan

The proposed strategic plan for the LWS TR&T program derived from the LWS TR&T Science Definition Team report of November 2003. The main points of this report were:

- LWS is a systematic, goal-oriented research program targeting those aspects of the Sun-Earth system that affect life and society.
- The TR&T component of LWS provides the theory, modeling, and data analysis necessary to enable an integrated, system-wide picture of heliophysics science with societal relevance.
- The successful implementation of TR&T depends on the adoption of the following principles:
    - Support data analysis and the development of theories and models that directly address TR&T priority targets, and that have potential societal benefits;
    - Require all TR&T-supported activities to identify deliverables with clear relevance to the program's goals and establish schedules and milestones for delivery;
    - Give particular emphasis to cross-disciplinary research;
    - Support synergistic activities such as workshops and summer schools to facilitate cross-disciplinary activities and to foster the development of an infrastructure for mentoring and development of personnel for heliophysics science;
    - Support the development of certain strategic capabilities that have broad potential use for science and application;
    - Support model testing and validation when appropriate for comparison with available data;
    - Support tools and data environment development relevant to LWS goals and objectives; and

- Support both small and large research proposals.

Based on the guiding principles specified by the Science Definition Team, the TSC updated the LWS TR&T strategic goals for the next decade:

1. Solar energetic particles and galactic cosmic rays pose major radiation hazards for space hardware and astronauts. Penetrating particle radiation adversely affects aircraft avionics and potentially the health of airline crews and passengers on polar flights. Communication and navigation systems are directly affected by impulsive changes in the solar particle and electromagnetic output leading to re-routed polar flights and GPS outages. In support of NASA's Vision for Space Exploration and the national communication, navigation, and transportation infrastructure, the TR&T needs to deliver the understanding and modeling required for useful prediction of the variable solar particulate and radiative environment at the Earth, Moon, Mars and throughout the solar system;

2. One of the major challenges facing humanity is global climate change. In order to gauge the response of the terrestrial climate system to natural and anthropogenic forcings, the TR&T needs to deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales;

3. National infrastructures are increasingly dependent on satellites orbiting Earth. With increasing miniaturization these systems are ever more sensitive to variations in the near-Earth space environment. To protect these assets, the TR&T needs to deliver the understanding and modeling required for effective forecasting/specification of magnetospheric radiation and plasma environments;

4. The upper atmosphere and ionosphere is central to a host of space weather effects, ranging from anomalous satellite drag, GPS position error, radio blackouts, radar clutter and geomagnetically induced currents (GIC). In order to mitigate space weather's impact on life and society NASA's LWS/TR&T in conjunction with other national agencies such as NSF and DoD needs to deliver understanding and predictive models of upper atmospheric and ionospheric responses to changes in solar electromagnetic radiation, and to coupling above and below.

These strategic goals will guide the selection of focused science topics for FY08 and beyond, as well as the selection of strategic capabilities. The figure below captures the complexity and high level of interconnections among the main elements and it summarizes our system-level understanding of the LWS components and their top-level interactions. The primary goal of the LWS program is to make progress in understanding this complex system, focusing on the most critical interconnections.

## 2 Process

In our deliberations we considered community input and used scientific and programmatic criteria to select the final recommendations.

Our recommendations recognize that "LWS is a systematic, goal-oriented research program targeting those aspects of the Sun-Earth system that affect life and society." This places several requirements on the proposed focused science topics and strategic capabilities, in particular that they should demonstrate some relationship to "Living" (i.e., have potential societal benefits) and to "Star" (i.e. be the result of variations in some form of the Sun's energy output).

# 3 Recommended FY08 Focused Science Topics

A balanced TR&T program might be expected to have two or three focused science topics for each strategic goal listed above. Thus, in selecting the most appropriate focused science topics, we have grouped them according to the four goals.

## 3.1 Focused science topics for Strategic Goal 1 (Solar storms)

### *3.1.1 Exploring the magnetic connection between the photosphere and low corona*

Target Description

Many LWS models of the corona and heliosphere depend on boundary conditions at the coronal base (the lowest altitude where the plasma beta is small), yet observations of the magnetic field come mostly from the photosphere below. It is therefore vital to understand how the magnetic field maps from the photosphere, through the chromosphere and transition region, and into the corona. This region of the atmosphere is also important for other reasons. For example, much of the UV radiation that drives the ionosphere/thermosphere system originates in the chromosphere and is determined by the chromospheric heating and structure. It has also been proposed that the waves that accelerate and heat the solar wind may be generated by magnetic reconnection events in this region.

A host of new observational sources of the solar atmosphere (including high resolution and high cadence photospheric vector magnetograms) are coming on line, which promise to promote real progress in the predictive qualities of these LWS coronal and heliospheric models.

To realize this progress, we need to understand the implications of these new observations for the structure and dynamic behavior of the intervening chromosphere and transition region. Therefore we invite proposals with the goal of improving our ability to model this critical region with the explicit long-term goal of improving the predictive capabilities of coronal and heliospheric models, and the ionospheric/thermospheric models which depend upon solar UV emissions.

Goals and Measures of Success

The measures of success for this topic are the impact of the science advances made by the team in improving the predictive capabilities of our current models.

Types of Investigations

This group will include theoreticians, numerical modelers and observers. Proposals which address this topic should use high resolution magnetogram directly or couple with other team models which do so. Examples of investigations which we would encourage, could consider

- as a goal, improved boundary conditions at the inner boundary of coronal models
- through modeling, to provide a physical interpretation of UV data and images

- understanding of the source of chromospherically generated waves which heat and accelerate the solar wind.

### *3.1.2 Determine the Conditions Leading to CME Onset*

Target Description:

Although there has been significant progress in recent years on theories for explosive eruptions, many important questions remain unanswered and require observational resolution. For example, the pre-eruption magnetic topology is still an issue of intense debate. It is not clear what role flux emergence and/or flux cancellation plays in coronal mass ejection (CME) onset. The role of helicity is far from understood. Furthermore, the roles of magnetic shear and magnetic complexity are unresolved. All these issues need to be clarified if LWS is to enable the development of a capability for predicting CME initiation. Given that Hinode and STEREO are delivering revolutionary new observations of the photospheric magnetic and velocity fields and of the coronal structures that give rise to CMEs (and will be joined shortly by SDO), it is now timely to mount a coordinated attack on the problem of identifying definitively the conditions leading to explosive eruptions.

Goals and Measures of Success:

The goal of this Focused Science Topic is to quantify accurately the timing and magnitude of developments in the photosphere and corona that lead to CMEs. The prime measure of success for this work would be a substantial improvement in our ability to determine where and when solar eruptions are likely to occur.

Types of investigations:

It is expected that the focus team will include, but certainly not be limited to, the following types of investigations:

- Observational and theoretical/modeling investigations relating to understanding the solar subsurface and atmospheric conditions that give rise to the regions responsible for CMEs;
- Observational and theoretical/modeling investigations relating to understanding the pre-CME magnetic and plasma structure;
- Observational and theoretical/modeling investigations relating to understanding the evolutionary paths and trigger mechanism(s) leading to eruption.

## 3.2 Focused science topics for Strategic Goal 2 (Sun-Climate)

### *3.2.1 Responses of atmospheric composition and climate to solar spectral variability and the energetic particle environment.*

Target Description:

Solar radiative forcing of the atmosphere is global in scale but drives regional physical processes that change with altitude. With the recent availability of comprehensive solar spectral measurements and models, quantification of the full range of solar effects throughout the atmosphere and ionosphere is now possible. Additional solar-driven variation is caused by the energetic particle environment, ranging from auroral fluxes to galactic cosmic rays, especially for chemically active minor species and the ionosphere. Models of the atmosphere that fully exploit the available estimates of external energetic inputs should be developed and extended in order to address the known variability in the middle and upper atmosphere and the possible variation of the climate system.

Goals and Measures of Success:

The goal of this topic is to produce model descriptions of the atmosphere and climate that respond to realistic solar photon spectral radiation and also the energetic particle environment, to compare those descriptions to the available long-term and short-term measurements of temperature, density, and chemical composition, and to quantify the climate sensitivity to external forcing of various types. The measure of success will be the ability to obtain closure between observations and models of short-term, solar-cycle, and long-term variability as functions of altitude.

Types of investigations:

Global and regional dynamical model development, process models and models of intermediate complexity (e.g., 1D and 2D approximations for long-term studies), data analysis and intercomparison studies, and global descriptions of external energy drivers, are examples of investigations solicited under this topic.

### *3.2.2 Solar Modulation of the GCRs and the production of cosmogenic isotope archives of long-term solar activity, used to interpret past climate changes.*

Target Description:

This topic addresses the physical processes that relate variations in solar radiative output to the variable flux of cosmic rays that produce cosmogenic isotopes. Cosmogenic isotopes ($^{14}C$ and $^{10}Be$) archived in tree-rings and ice-cores, respectively, provide unique information about levels of solar activity over many thousands of years prior to the early seventeenth century, when sunspot observations commenced. Correlations of many paleoclimate variables (e.g., $^{18}O$ indicators of temperature or precipitation) with the cosmogenic isotopes suggest that climate has been responding to solar forcing throughout the Holocene. Even though cosmogenic isotopes vary in response to the flux of galactic cosmic rays at Earth, and thus to modulation of the heliosphere by open magnetic flux, the correlations are typically attributed to variations in solar radiative output, which arise from changes in the closed magnetic flux that produces features in the solar atmosphere such as sunspots and faculae.

Needed for reliable interpretation of paleo Sun-climate relationships is a physics-based understanding of the relationship between radiative output and cosmogenic isotopes that takes into account the quite different processes within the entire sun-earth system that produce their variations.

Goals and Measures of Success:

The goal is to identify and characterize the respective solar-driven processes that simultaneously, but by distinctly different processes, modulate both solar radiative output and heliospheric structure, composition and hence the flux of galactic cosmic rays. A measure of success is a quantitative relationship between time series of solar radiative output and cosmogenic isotopes, on multiple time scales. Other measures of success include improved specification of cosmic ray transport/attenuation in the heliosphere, and/or deposition/transport in the Earth's atmosphere as functions of solar activity.

Types of investigations:

Relevant investigations include empirical and model investigations of the organization of solar magnetic fields into closed and open flux, as a result of transport by solar differential rotation, diffusion and meridional flow. Quantitative determinations of the solar-driven heliospheric modulation of galactic cosmic rays by transport, attenuation and interactive processes are also relevant, as are investigations of other physical processes within the Sun-Earth system needed to quantitatively relate electromagnetic radiation and cosmogenic isotopes. Studies of the deposition and transport of the cosmic ray fluxes in the Earth's atmosphere are also solicited.

## 3.3 Focused science topics for Strategic Goal 3 (Near Earth Radiation)

Prioritization:

- Radiation belt topic is suitable for a focus team and is the recommended topic for this strategic goal.
- However, the SEP topic is one that industry (the "society" LWS is supposed to serve) really cares about. The pool of proposals this is likely to draw is small (Aerospace, Mary Hudson & Co, a few at LASP and LANL, possibly AFRL). This would make an excellent candidate for an independent investigation and could be called out as such in the call.

SEP topic:

- This is a logical progression from previous year's focus groups – which have dealt with origin, production and subsequent transport, the missing part is the impact on magnetospheres.
- It's the most important space weather particle population with major effects on technological systems.
- Science – formation and de-trapping of transient high energy proton belts in the slot region is not fully understood – esp. their relation to the magnetospheric dynamics at the time. Also, existing models on SEP cutoffs are not accurate.
- 2004 topic on "Formation and loss of new radiation belts in the slot region" did not really deal with new energetic proton belts, it focused on the "adjacent outer zone flux peak around L=4" and almost exclusively focused on the relativistic electron dynamics problem.
- Large impact on society, also one of the topics called out during the recent NASA SET workshop.

Radiation Belt dynamics topic:

- Many of the current pieces of the dynamics (acceleration, loss or transport) have been investigated and now also have a good body of theoretical and modeling work behind them.

They are ripe for integration – a lot of which will depend on the data to be returned by RBSP. However, what is missing is a comprehensive assessment of the impact of the input data that any of our developed and developing models need to use, plus the accompanying assumptions. Input to most models is data from GEO – yet the global state of the 6-12 Re region is undercharacterized. How important is knowledge of the spatial distribution of plasma along the inner edge of the plasmasheet? The composition? How important are impulsive events (substorms, BBFs - Themis can help here)?
- For the ring current and radiation belt models, how important are assumptions on wave structure, spatial and frequency distribution? How much do pitch angle and energy diffusion calculations depend on assumptions of wave propagation, field line density distributions, etc? Assumptions on plasmapause position and structure?
- The idea here is to call for investigations that perform parametric sensitivity studies on existing models to identify the most controlling factors and the most important missing bits both in terms of data and physics – and to focus on the specification and modeling of the 6-12 Re transition region.

### 3.3.1 Toward combined models of acceleration, loss and transport of energetic electrons and protons in the magnetosphere

Target description:

Radiation belt electrons and protons create a hazardous environment for spacecraft operating in Earth orbit. In recent years we have significantly advanced our understanding of loss, source and transport mechanisms operating in the magnetosphere. A global understanding of the influence of the plasmasphere, plasmaspheric plumes, magnetopause location, ULF and VLF plasmawaves, and ring current particles and electric and magnetic fields is required for prediction of the dynamics of the radiation belts. Two complementary modeling approaches are used in radiation particle studies – Global MHD and particle transport. It is necessary and now possible to combine studies of various magnetospheric processes that populate the ring current, electron and proton radiation belts and to identify the important missing ingredients of both physics and measurements. This includes the critical transition region in the near-Earth (6-12$R_E$) magnetotail. This research is timely for preparation of the Radiation Belt Storm Probes (RBSP) and would leverage the complementary GEM focus group on “Space Radiation Climatology” and “Near-Earth magnetosphere: plasma, fields, and coupling”.

Goals and measures of success:

The research objectives include: (1) development of models of the dynamics of the radiation belt electrons and protons and the transition regions; (2) determining how transition region fluxes, ring current particles, plasmasphere, plasmaspheric plumes, electromagnetic waves, and variations of the magnetospheric electric and magnetic fields affect the radiation belt electrons and protons; and (3) an assessment of the importance of the individual constituents and their controlling parameters (inputs) in the overall evolution of the radiation belt system. The measure of success is the improvement of our capabilities to predict the dynamics of radiation belt fluxes.

Types of Solicited Investigations:

Proposals that address this topic should address multiple components of mechanisms by which radiation belt particles are accelerated, lost and transported. The research objectives of proposals include: (1) modeling dynamics of the radiation belt and transition particles (2) determining conditions in the magnetospheric environment under which one or several mechanisms dominate; (3) coupling magnetospheric codes (4) developing models with data-assimilative capabilities or combining models with data (performing reanalysis) and (5) model based sensitivity studies to establish the importance of model input parameters (data / boundary conditions / assumptions).

### *3.3.2 Magnetospheric and Ionospheric Impact of SEP Spatial and Spectral Distribution*

Target description:

Solar energetic protons (SEPs) are a major, highly variable, component of the energetic (50keV to 10 GeV) particle population impinging on the Earth's magnetosphere. Their arrival at the Earth's magnetosphere can increase the energetic population near the Earth by a factor of 10-1000, and lead to the formation of new high energy ion radiation belts. Magnetospheric dynamics, the interconnection between the terrestrial and the interplanetary magnetic field, and the distortion of the magnetosphere caused by the arrival of interplanetary shocks, control the entry of SEPs with energy up to tens of MeV, and the formation of new radiation belts. In the polar regions, SEPs that are not trapped enter into the atmosphere and cause anomalous ionization and radiation in the middle atmosphere. Calculation of the dynamical boundary between trapped and precipitating particles, and their consequent distribution and effects throughout the magnetosphere and atmosphere, is an important LWS goal.

Goals and measures of success:

The research objectives include: (1) observational determination of spatial and spectral properties of SEPs in the magnetosphere and ionosphere and (2) theoretical models and simulations of the entry and transport of SEPs in the magnetosphere and ionosphere. The results would be a quantitative understanding of the importance of SEPs on the particle populations in the magnetosphere and ionosphere. An important metric of success would be the direct comparison of the observations and empirical models with theoretical models and simulations.

Types of Solicited Investigations:

Proposals that address this topic should consider mechanisms which control entry and transport of SEPs in the magnetosphere and polar ionosphere system. The research objectives of proposals include: (1) statistical or empirical characterization of the particles (2) physical modeling of the SEP populations in the magnetosphere and polar ionosphere, and their transport and (3) investigations of the types of magnetospheric dynamics conducive to SEP trapping and de-trapping.

## 3.4 Focused science topics for Strategic Goal 4 (Ionosphere-Thermosphere)

### *3.4.1 Thermospheric wind dynamics and their influence on the coupled ionosphere-thermosphere system*

Target Description:

Investigate the origins and effects of thermospheric winds and their variability with solar and magnetospheric activity, season, tides and other forcing mechanisms from the lower atmosphere. Thermospheric winds, both horizontal and vertical, are driven by solar heating, magnetospheric energy and momentum inputs at high latitudes, and tides and other waves propagating up from the lower atmosphere, all of which have large variability. The winds modify the global thermospheric density and composition, and strongly impact the ionosphere both directly, through ion transport, and indirectly, through influences on the production and loss of plasma and the generation of dynamo electric fields. A detailed understanding of the global thermospheric wind system and the sources of its variability is essential for improving our ability to develop useful predictive models of satellite drag and ionospheric electron density variations.

Goals and Measures of Success:

The goals of this focused science topic are to improve model descriptions of thermospheric wind processes, to enhance our understanding of winds with direct and indirect observations, and to achieve better quantification of the role of winds in causing thermosphere/ionosphere variability. Measures of success will include improved predictive capability of climatological and storm-driven model descriptions, convergence between thermosphere and ionosphere observational parameters, and consistency between measurements of energetic inputs and thermospheric and ionospheric responses.

Types of Investigations:

Satellite and ground-based observational analysis, modeling of the coupled thermosphere and ionosphere, analysis of thermospheric wind response to solar and magnetospheric energy inputs, and theoretical studies that elucidate the role of winds in causing thermospheric and ionospheric variability.

### *3.4.2 Determine the sources of daily variability in the thermosphere and ionosphere*

Target Description:

Understanding the day-to-day variability of the ionosphere and thermosphere remains an outstanding problem. It is a key to unraveling the relative strengths of two primary forcing mechanisms of the I-T system: photon-driven versus particle/plasma driven solar energy input changes. The responses of the I-T system to each mechanism is strongly inhomogeneous, depending for example, on altitude and geographical location (photons are input primarily at low-mid latitudes whereas geomagnetic effects commence at higher latitudes and propagate to lower latitudes). Forcing from below must be considered also. Understanding inter-day variability will improve space weather predictions under nominal conditions. It will also improve storm-time predictions by providing an accurate baseline prior to the initiation of geomagnetic disturbances.

Goals and Measures of Success:

The goal of this topic is improved understanding of the observed day-to-day variability of the ionosphere-thermosphere including thermospheric densities, composition, winds, and ionospheric electron densities. Successful investigations will use observations and modeling to quantify the causes of variability. Improved predictive models of short-term space weather effects are an expected outcome. Multi-disciplinary perspectives are especially encouraged that account for temporal variability of the drivers such as solar photons and the solar wind.

Types of Investigations:

We solicit empirical characterizations of day-to-day variability using recent data and observational methods. Observations, models and combinations that identify the relative roles of solar forcing and internal dynamics in creating observed daily variability. Multi-disciplinary investigations that characterize how the broader heliospheric environment affects daily variability are especially encouraged.

## 3.5 Ensemble forecasting and data assimilation for space weather applications

An increasing number of models are being developed that provide information with potential value for space weather applications. Many of these models are being run routinely, either at modelers' home institutions, at the CCMC, or at one of the U.S. and foreign operations centers. An important challenge when using these models for decision making (such as when to re-route a commercial airline flight or to modify the operations of a power grid) involves knowing what the level of uncertainty is of a given model and knowing under which conditions one model's predictions should be given higher weight than those of another. The focus of this topic is to provide quantitative comparisons of one or more models over significant time periods (ideally over at least a solar cycle), with the goal of introducing/maturing ensemble forecasting as a viable technique for space weather and providing statistical measures of ensemble forecasts. Emphasis should be placed on modeled parameters that relate to the onset, magnitude, and duration of space weather disturbances, such as solar flares, solar energetic particle events, solar wind stream structure, geomagnetic disturbances, radiation belt electrons, and ionospheric disturbances. The results of these studies would be to understand how to optimize our current models for space weather applications, to assist in the implementation of ensemble forecasts at the operations centers, and to determine where future research could be focused to address the most important deficiencies in our predictive capabilities.

Closely related to ensemble forecasting are a range of data-assimilative methods (e.g. Kalman Filters) that can be used to assess and improve the performance of models. Inclusion of data can lead to a more accurate representation of the current state of a system and thus to a better basis for subsequent forecasts. Data assimilation methods may also offer a rigorous way of assessing model fidelity by providing a measure of times and locations where models and data systematically diverge; and this may thus point to either missing physics, false assumptions or inadequate parameterization of model processes. The focus of this topic is to provide data assimilative frameworks for space weather related models and to adapt existing data assimilation methods for use in a relatively sparse data environment. A critical part of this process needs to be the provision of high fidelity and inter-calibrated data products that are essential in order to make use of data from as many sources as possible.

# 4 Recommended FY07 Strategic Capabilities

## 4.1 Solar Spectral Irradiance Models on Multiple Time Scales, and Coupling to Atmospheric/Climate Models

Capability Description:

Estimate the solar spectral irradiance from 1 to 2500 nm based on solar imagery or wavelength proxies.

Many atmospheric/climate models employ out-dated and inadequate solar irradiance inputs that do not take into account the most recent state-of-the art observations, models and knowledge of the variations, such as the spectral dependence of the irradiance variations. Typically, the spectrum is divided into rather broad bands and the atmospheric transmission/reflection/radiation processes are compromised as a result. Improvements are needed not only in the irradiance variability inputs (models) but also in the way that the climate/atmospheric models use these inputs.

LWS Strategic Need:

The sensitivity of the Earth's atmosphere to incident solar irradiance is highly wavelength dependent, allowing variations in solar radiation to affect different layers in the Earth's atmosphere. With the recent mission launches of TIMED (2001) and SORCE (2003), whole atmosphere modelers now have daily solar spectral irradiance observations spanning 1 nm to 2700 nm, and these newly available data are beginning to be used in models of atmospheric energy transport. Correlating these new spectral irradiance data with readily observable manifestations of solar magnetic activity will:

- identify portions of irradiance fluctuations which are attributable to different manifestations of solar magnetic activity; and
- allow estimates to be made of solar spectral irradiance based on ground – or space – based solar images.

This model may be the only means of spanning expected upcoming gaps in spectral irradiance observations after the conclusion of the SORCE mission, when measured spectral irradiances will be limited to wavelengths shorter than 127 nm, which is the long-wavelength limit of the EVE experiment on SDO. Such models may facilitate simpler future instruments if measurements at select wavelengths can be identified that allow accurate estimates of full spectral irradiances.

Desirable Features:

- Correlates measurements of solar spectral irradiances with solar features and magnetic activity;
- Uses existing spectrally continuous solar irradiance data from the last few years of spacecraft measurements;
- Spans the spectral range available from current spacecraft instruments (1 to 2500 nm);
- Uses existing ground- or space-based solar images for feature identification;
- Estimates solar spectral irradiances in absence of temporally nearby irradiance data (i.e. without relying on extrapolation over time);

- Estimates irradiances through times of extreme solar activity as well as during times of

minimal activity.
- Identifies select "proxy" wavelengths from which accurate, spectrally continuous solar irradiances can be estimated.

Though not required, investigations that lead to improved physical understanding of the Sun are at an advantage.

## 4.2 Development of an integrated model of the atmosphere and ionosphere, with state-of-the-art interfaces to solar spectral irradiance inputs, the plasmasphere/inner-magnetosphere and lower atmosphere.

Capability Description:

Develop and release for community use an integrated model of the Earth's atmosphere and ionosphere with state-of-the-art solar forcing, auroral processes, high-energy particle processes, and the capability for coupling to magnetospheric models.

LWS Strategic Need:

Understanding the upper atmosphere and ionosphere response to space weather effects is central to LWS strategic goals. On longer time scales, a full quantification of the effects of solar forcing, through irradiance changes, magnetospheric coupling, and high-energy particle effects, is also important for a full understanding of systematic changes in the atmospheric system. There is compelling evidence that lower atmosphere variability is critical to the understanding of upper atmospheric variability and space weather. In addition to driving the mesospheric circulation away from radiative equilibrium, atmospheric gravity waves can significantly affect the amplitude, phase, and vertical propagation of tides and planetary waves in the mesosphere and lower thermosphere. Observations have shown that non-migrating tides can be as strong as the migrating components, and excitation of these tides due to tropospheric latent heat release and interactions with planetary waves can have profound impacts on the temperature and composition of the mesosphere and thermosphere, and the structure of the ionosphere. Thus, models that properly couple the atmosphere and ionsophere must be employed to achieve more realistic descriptions of space weather processes, and, conversely, the ability to couple solar and magnetospheric models into the entire atmospheric system is needed in order to answer the fundamental question of how deeply into the terrestrial atmosphere the effects of variable solar-driven processes can penetrate.

Desirable Features:

- Models of fully coupled atmospheric and ionospheric processes.
- Capability for lower-boundary specification using sea surface temperatures and/or lower atmospheric fields.
- Tidal and gravity-wave generation and propagation schemes.
- Model descriptions of atmospheric chemistry and minor species, with radiative and energetic coupling to the temperature field.
- Full description of all solar irradiance effects throughout the atmosphere and a means of using modeled and/or measured solar spectra as input.
- Model descriptions of thermospheric dynamics, diffusive processes, and temperature structure.

- Model descriptions of ionospheric processes, including electrodynamics, ion composition, and ion and electron temperatures.
- Parameterization of auroral precipitation and convection in response to magnetospheric forcing.
- Parameterization of energetic particle transport and effects throughout the atmosphere.
- Capability for coupling to models of the magnetosphere and the solar wind.
- Capability for extension into the plamasphere, and coupling with ring-current and radiation-belt models.

# 5 Tools & Independent science

## 5.1 Tools and Methods

The Tools and Methods component supports studies that, by themselves, may not deliver significant new science understanding, but instead deliver tools and/or methods that enable critically needed science advances. Examples include the development of new empirical methods or analysis techniques, such as local helioseismology, that can be used to forecast solar, interplanetary, and geospace activity, and the development of software tools that can identify, retrieve, assimilate, and/or portray data in order to model results from different sources for LWS research and forecasting objectives. Tools that address the four LWS TR&T strategic goals will be especially welcome.

A deliverable product(s) must be specified along with a delivery date. The deliverable product can be, for example, a stand-alone product or a web application, and must be delivered to a LWS approved repository/server such as the CCMC or an existing VxO. The delivery date must be during the final year of work with enough time left to support appropriate documentation and handover to the CCMC/VxOs to insure longevity and to enable its independent use by the scientific community. All tools will be listed with links from the LWS TR&T web site (http://lws-trt.gsfc.nasa.gov).

## 5.2 Independent Investigations

The Independent Investigations component supports studies that can be a test bed for future focus topics or fill gaps or deficiencies in fundamental understanding. The Independent Investigations component allows flexibility for cutting edge ideas that may be immature or too tightly focused to form a focus team, or lacking tools that could lead to rapid closure. The criteria that determine whether a proposed study should be submitted to this component are its urgency and impact to the LWS strategic goals listed above; proposals should demonstrate potential societal benefits and be the result of variations in some form of the Sun’s energy output. Some examples of Independent Investigation that would be especially welcome for this year include:

- spatial and spectral distribution of Solar Energetic Particles (SEPs) in the magnetosphere and ionosphere.
- TBD from list that is not selected as Focus Area.

# 6 Recommendation about HelioInformatics

Karel Schrijver gave a presentation to the Steering Committee about the proposed “heliophysics discovery infrastructure." This would be a tool set to identify, classify, quantify, and catalog properties of features and events in large volumes of multi-dimensional data from all heliophysics observatories and models. In essence this would be a dedicated data-mining tool for heliophysics. The cost of this development would be about $5M/year, clearly beyond the scope of the NASA LWS TR&T program.

Highest priority to the LWS TR&T program is on ensuring scientists' access to the huge data sets coming down from LWS missions and on developing tools to enable analysis of these data sets on a reasonable time scale. This can be done with more limited resources and supported at the LWS or Heliophysics level. We should leverage existing efforts to the maximum extent possible.

The proposed Helioinformatics infrastructure would be very useful for all components of the Science Missions Directorate. In fact, a very similar concept is being explored by the Earth Science Division. In our view further study is needed and we suggest that the SMD creates a study group, including Heliophysics and Earth science, to present a recommendation to NASA.

# 7 BARTOL NEUTRON MONITOR SUPPORT

The SC is not informed enough about the scientific usefulness of the neutron monitors. Most members are not familiar with neutron monitor observations and we were not briefed about the scientific impact of the planned action. We cannot judge the importance of this continuing data set without additional information.

# 8 LWS POSTDOC COMPETITION

The TSC recommends the creation of a new and prestigious LWS Postdoc competition as a visible commitment of the LWS program (potentially as a separate NRA) to support researchers who intend to work in this field and have recently received their Ph.D. degree. The program would allow successful candidates to request limited support for LWS research activities of their own devising.

### 8.1.1 PI Eligibility:

The researcher to be supported must have received his/her Ph.D. in a relevant discipline within the past 3 years or expect to be in a postdoctoral research position by the time the award is made. Candidates may submit no more than one proposal in response to this program solicitation in any given year. He/she should appear on the proposal as the sole Principal Investigator provided his or her institution allows this. If the institution does not allow postdoctoral researchers to act as PIs on research grants, then the researcher's advisor at the institution may appear as the sole PI, and the candidate should be listed by name in the Senior Personnel section of the budget.

### 8.1.2 Description

An important goal of the LWS program is to foster the development of a new generation of researchers involved in the theory, modeling, and data analysis necessary to enable an integrated, system-wide picture of heliophysics science with societal relevance.

The anticipated typical award is about $100,000 per year. Awards will be limited to a maximum duration of three years. The project description may be brief and must not exceed 5 pages. The project description need only include a synopsis of the type of LWS-related research that is to be carried out. The postdoctoral researcher's biographical sketch must be included in the biographical sketch section of the proposal.

In addition to the standard items required in a LWS proposal, a letter indicating the host institution's interest in pursuing this project must also be included, along with two letters of recommendation, an abstract of the candidate's doctoral thesis, and a transcript of the candidate's graduate course work.

The LWS postdoctoral research awards will provide a stipend of $50,000 per year for the postdoctoral researcher, plus appropriate amounts for benefits, travel, publishing expenses, and indirect costs. This does not preclude the receipt of additional support from other sources. However, awards made under this Program Solicitation may provide salary or stipend support for only the postdoctoral researcher.

Reviewers will be asked to comment on the relevance of the proposed research to the LWS program objectives. They will also be asked to comment on the qualifications of the researcher based on the letters of recommendation, transcript of course work, and the quality of the researcher's previously published work.

## 9 Questions to 2004 Focus teams

- What overall progress has been made by your team and where does this fit within the LWS strategic goals?
- What unresolved questions remain that need to be addressed urgently?
- What models or model improvements need to be developed before more progress in your area can be made?
- What kinds of data need to become available before more progress in your area can be made? Of these data, which just need to become accessible to a wider community and which are new measurements requiring new instrumentation? Be specific.
- Is the problem you are working on mature enough to define a "Strategic Capability?"
- What value did the team concept bring to the scientific output of the group?
- How will the community access your results and products?

## 10 Joint Focus Topics with Planetary

### 10.1 Extreme SEP events – predictions and impacts on human space flight

Target description:

Solar energetic protons (SEPs) are a major, highly variable, component of the energetic (50keV to 10 GeV) particle population impinging on the Earth's magnetosphere and present throughout the solar system. They pose one of the major threats to human spaceflight, in particular for extended missions (interplanetary missions outside the shielding of planetary magnetospheres), where one or two extreme events may deliver the total anticipated dose for the whole mission. A more detailed understanding of extreme SEP events, both from a statistical, historical point of view and from a scientific perspective examining the solar and interplanetary conditions conducive to producing such events, is an important LWS goal.

Goals and measures of success:

The research objectives include: (1) observational determination of historical records of extreme SEP events and their detailed characterization and (2) theoretical models and simulations to establish solar and interplanetary conditions that lead to extreme events near the Earth/moon system. The results would be a quantitative understanding of the probability of occurrence of extreme SEP events and a detailed record of past events that have been observed. An important metric of success would be the ability to correctly predict the occurrence of a recorded extreme event based on the available historical data from the sun and the solar wind.

Types of Solicited Investigations:

Proposals that address this topic should consider statistical / historical observational data and existing models that address the production and propagation of SEP events. The research objectives of proposals include: (1) statistical or empirical characterization of extreme SEP events (2) long term historical evidence of extreme SEP events based on geological records (3) observational and theoretical investigations of the solar conditions conducive for production of extreme events with the aim of establishing reliable "indicators" for upcoming activity and (4) observational and theoretical investigations of the types of solar wind structures (shocks) conducive to contributing to extreme SEP events.

# 11 OTHER

## 11.1 2 hour Town Meeting at Fall AGU

1 hour Q&A

1 hour 2004 focus team reports