NASA Living with a Star (LWS) Targeted Research and Technology (TR&T) Steering Committee (SC) Report, 2009-2010

Date of Report : June 11, 2010

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The Steering Committee conducted its deliberations primarily in three meetings in the Washington DC area (February 22-23, April 8-9, and May 5-6, 2010), where members participated either by direct attendance or by calling in. In addition, members communicated with each other by e-mail and teleconferences. The Agenda items for the meetings essentially centered on four topics:

- Review of the LWS TR&T Program (*Section I*)
- Suggestions for 2010 Focused Science Topics (FSTs) (*Section II*)

- Advanced Computational Capabilities for Exploration in Heliophysical Science (ACCEHS): Organization of a Grass-roots Initiative and Workshop (*Section III*)
- The Heliophysics Summer School: Going Forward (*Section IV*)

I. Review of the LWS TR&T Program

The 2009 SC Report (for details, see http://lws-trt.gsfc.nasa.gov/trt_screport09.pdf) recommended a number of changes in various elements of the LWS TR&T Program (hereafter referred to as the Program). Some of these changes were already in place in 2008, and the remaining changes went into effect in 2009. The principal recommendations were as follows:

1. The funding duration for the FST teams should, in general, be up to a period of four years. The funding for the fourth year will be contingent on a review at the end of the third year on the progress made by each team member on the integrated research plan, developed within the first three months of funding, with schedules, milestones, and deliverables.
2. In order to be compliant, every proposal submitted to the Program must include a section entitled "Proposed Contributions to the Focus Team effort."
3. The Independent Investigations Element of the Program has not proven to be effective and should be eliminated, at least for 2009.
4. A new Program on the Sun-Climate Theme should be started in 2009.

The 2010 SC discussed these recommendations, and suggested that they should continue. Consistent with recommendation 2, ten proposals out of a total of 137 submitted in 2009 were returned as noncompliant. With two proposals withdrawn, there were 125 compliant proposals in 2009 in the categories of FSTs, the Sun-Climate Theme, and Tools and Methods.

The SC discussed at some length the broad interdisciplinary scope of the Program. Since its inception in 2004, the Program has covered 31 FSTs, which can be broadly grouped under the topics of solar dynamics and magnetic structure, energetic particle acceleration and transport, magnetosphere/ionosphere/thermosphere dynamics, and Sun-Climate connection. The Program has supported 6 Strategic Capabilities: 3 under the auspices of NASA/NSF/AFOSR Partnership for Collaborative Space Weather Modeling in 2005, 1 in 2006, and 2 in 2008, and a variety of investigations under Tools and Methods. Based on the presentations given annually by the participants in the Program at the Fall AGU Meetings and submitted reports, the Program appears to have some unique attributes:

- Although the integrated research programs of all FST teams do not appear to be uniformly successful, many teams are successful in producing high-quality integrated research programs that are more than the sum of the parts. The participants of successful teams describe their collaboration as one with high impact for their own programs as well as their discipline.
- By its emphasis and structure, the Program enables significant interdisciplinary research.

- The process of developing topics by a SC, which actively solicits and receives input from the community is seen as a vital connection that is renewed every year, making the Program responsive to new developments and common threads of discovery across heliophysics science.

The SC judges that these unique features of the Program have served it well. However, given that the Program has been in existence for 7 years, and that a broad range of FSTs and Strategic Capabilities have been executed, it is timely to conduct a more comprehensive assessment of how well the concept is working, how it could be improved, and whether it could profitably be extended to other programs. This task will require substantial time and personnel resources, beyond the scope of the usual SC. *Therefore, the SC recommends that the Program convene a Task Force which will (i) assess, with input from the community as well as the Program Scientists, the accomplishments and effectiveness of the Program, (ii) scrutinize the topical coverage of and possible gaps in the Program, and (iii) propose mechanisms by which the program may be strengthened further and given greater visibility.*

II. Suggestions for 2010 Focused Science Topics (FSTs)

The SC devoted a considerable amount of time in developing suggestions for 2010 FSTs. Most of the proposals had their roots in ideas put forward online and by e-mail by members of the community, which reinforces the importance of community participation in the process. The following is a list of the proposed FSTs (the order is not prioritized):

Low-To Mid-Latitude Ionospheric Irregularities and Turbulence

Target Description:

The ionosphere plays a major role in space weather due to its important influence on the propagation of electromagnetic waves. Changes in this propagation can significantly impact communication and navigation systems primarily through the development of electron density irregularities and plasma turbulence, often in the vicinity of large electron density gradients. Associated irregularities and turbulence can have a spatial range from tens of kilometer through centimeter scales, and temporal scales from milliseconds to tens of minutes. A wide variety of physical processes occur on these disparate scales, and for decades this has posed a considerable challenge to the goal of a truly self-consistent, comprehensive model-based understanding of irregularity dynamics and morphology.

However, recent developments have presented new opportunities to make significant advances in our understanding of irregularity physics. Large observational databases from ground based radar and satellite platforms (e.g. Jicamarca radar, SuperDARN HF radar, DMSP, C/NOFS, DEMETER, GPS TEC) are available for a wide range of appropriate irregularity scale sizes. For example, recent observations by the C/NOFS spacecraft provide unprecedented measurements of the equatorial ionosphere that enable timely, high-resolution studies of ionospheric irregularities. Total electron content (TEC) measurements between the CERTO beacon and a ground network of receivers near Jicamarca Radio Observatory provide the unprecedented opportunity of imaging the genesis of equatorial plasma instabilities and scintillation at high spatial resolution, and study the onset, evolution, and propagation of these irregularities. Moreover, recent advances in modern computer technology, kinetic and fluid models with sophisticated, realistic boundary conditions and high resolutions have recently become available. A focused team effort to apply these new tools, constrained appropriately by observations, is timely and has significant potential to transform our knowledge of irregularities and advance our predictive space weather capabilities for their presence and effects.

Goals and Measures of Success:

The goals of this FST are to provide an improved understanding and a predictive capability of ionospheric irregularities and turbulence, and specifically, to identify the causal mechanisms of the irregularities based on theoretical and computational studies in conjunction with comparison to experimental data. Measures of success are the following:

- Development of improved models of E and F region plasma instabilities and turbulence,
- Establishment of the connection (if any) between E and F region irregularities,
- Identification of the causes of day-to-day variability of irregularities,
- Understanding of the connection between large-scale ionospheric processes and the development of electron density irregularities (e.g., equatorial spread F), and
- Development of a predictive capability for irregularity onset and evolution.

Types of Investigations:

- Theoretical studies of the linear and nonlinear development of ionospheric instabilities,
- First-principle modeling of ionospheric irregularities and turbulence in 2D and 3D (e.g., fluid, hybrid, PIC simulation models),
- Observational studies identifying regions of ionospheric irregularities and possible causal mechanisms, and
- Characterization of irregularities and turbulence as a function of geophysical parameters (e.g., latitude, longitude, altitude, F10.7, geomagnetic storm conditions etc.).

Episodic and Asymmetric Behaviors in the Ionosphere-Thermosphere-Magnetosphere System Driven by Non-southward IMF

Target Description:

Northward IMF with a large B_y component accompanied by high-speed solar wind flows can produce vigorous responses through the entire coupled ITM/geospace system. Solar wind pressure pulses can enhance and further modulate these effects. Thermospheric densities in particular can be altered in ways, which at times, markedly differ between hemispheres, in close correlation with changes in ionospheric densities, electric fields, conductances, convection patterns, and ion outflows. Other non-southward IMF drivers exist, often in combination, but their effects are less comprehensively studied.

Data from Low Earth Orbit (LEO) spacecraft reveal instances of episodic, localized dayside Poynting flux that exceed background levels by an order of magnitude during northward IMF. Neutral atmospheric disturbances created by these poorly understood solar wind-ITM perturbations affect LEO satellite control, precision pointing and associated mission operations. Simple orbit propagation simulations suggest kilometer-class position errors within 24 hrs for small satellite transiting regions of localized density enhancements. Some events are accompanied by elevated fluxes of soft electrons and medium energy protons that deposit energy at very high altitudes that further exacerbate the errors. Limited observations suggest a link between intense localized energy input and localized scintillations in the cusp/polar cap. There is a critical need to quantify and predict the behavior of space weather variables such as Poynting flux, precipitating particle flux distributions, hemispheric power, ionospheric outflows, and ionosphere and thermosphere density and composition for events driven during other than southward IMF conditions. Further, associated ion outflows have significant asymmetries in heavy ion magnetospheric mass loading and transport, significantly modifying plasma sheet and ring current development and intensity and modulating overall solar wind energy transfer. These characteristics alter ionosphere/thermosphere energy deposition and response, but their relative impact is not clear.

The rise in Solar Cycle 24 provides a timely motivation to investigate the geospace drivers and physics behind these impulsive and often asymmetric effects. Historical observations (e.g. POLAR, IMAGE, FAST) are available to complement current data from Cluster and THEMIS. This FST will leverage numerous assets. Ground based sensor networks and assimilative / empirical models provide information on ionospheric preconditioning and stormtime response. NSF's AMPERE satellite system will offer global field-aligned current monitoring. MHD and thermospheric simulations have new capabilities, offering the ability to follow energy flow. Efforts in this area would strongly link to GGCM activities and community M-I-T coupling interests. The SWARM mission, due to launch in 2011, would benefit from and contribute to focus team efforts.

Goals and Measures of Success:

The goal of this FST is to determine the origins of localized energy deposition and the nature of asymmetric and episodic system configuration and response, particularly in the auroral zone and near-cusp region of the ionosphere-thermosphere. Measures of success include:

- Quantifying the links between enhanced dayside field-aligned currents and Poynting flux, particle flux, ion outflows and their sources in the solar wind and the impacts in the magnetosphere-ionosphere-thermosphere system,

- Synthesizing observations from solar wind and magnetosphere missions and model and predicting their consequences in ionosphere-thermosphere system, especially as they relate to satellite drag and ionospheric outflow and scintillation,
- Determining the sensitivity of ionosphere/thermosphere energy deposition to asymmetric and episodic solar wind inputs compared to seasonally driven effects, and
- Improving predictive capabilities of GCM models in specifying asymmetric and episodic energy inputs and their consequences.

Types of Investigations:

- Assessment of the roles of impulsive IMF changes, variations in speed, and density perturbations, in effectively modulating asymmetric/episodic events,
- Modeling of field-aligned current systems and their relation to Poynting flux and particle energy deposition for IMF $B_Z>0$ and $|B_Y|>0$ conditions,
- Investigations of driver asymmetries and their relation to traveling atmospheric/ionospheric disturbances and high altitude wind perturbations,
- MHD-GGCM modeling of asymmetric perturbations, incorporating both ionospheric and thermospheric effects,
- Assessment of the roles of Poynting flux and particle flux in high-latitude ion outflows and their asymmetries,
- Studies of ionosphere/thermosphere energy deposition and plasma reconfiguration during asymmetric/episodic events, and comparison of their features to those during southward IMF conditions, and
- Determination of the effects of such events on satellite (and satellite constellation) location, pointing and control.

Incorporating Plasma Waves in Models of the Radiation Belts and Ring Current

Target Description:

In the collisionless plasma of the magnetosphere, changes in the energetic particle populations are controlled by interactions with plasma waves. Our ability to understand and model the dynamic variability of the radiation belts and ring current requires improved knowledge of the spatial distribution and properties of the important plasma waves in the magnetosphere and their variability due to changes in either solar wind forcing or geomagnetic activity. Major uncertainties remain, for example, on the spatial distribution and properties of EMIC waves, the spectral properties of equatorial magnetosonic waves, and the wave normal distribution of chorus emissions. The purpose of this new focus group is to fill in the gaps in our understanding of the key plasma waves and to advance the development of improved codes to treat the dynamical evolution of the ring current and radiation belt populations, including both the generation and the effects of plasma waves.

Goals and Measures of Success:

The goal of this Focused Science Team is to advance our predictive capabilities of ring current and radiation belt dynamics by incorporating improved models of plasma waves into our large-scale plasma and field models. This effort is timely in that it will combine modeling and observations to develop tools that can be used with the Radiation Belt Storm Probe mission, scheduled for launch in May, 2012.

Success of this team effort will be measured by: the improvement of our understanding of the spatial distribution and properties of waves in the inner magnetosphere from existing measurements; the development of empirical and physics-based models of the dominant wave modes; and the integration of new wave models with existing global MHD, ring current, and radiation belt models. The expected outcome of this effort is an improved understanding in the spatial distribution and important characteristics of the wave modes that affect radiation belt and ring current dynamics, as well as the ability to predict the regions of wave excitation and wave characteristics based on the modeled ion and electron distributions.

Types of Investigations:

- Utilize existing wave data (Themis, Cluster, POLAR, IMAGE, CRRES, AMPTE, SCATHA, Akebono, DE1, etc.) to determine the spatial distribution and properties of the dominant wave modes,
- Model the spatial distribution and the power spectral intensity of plasma waves, including those driven by and affecting the ring current and radiation belt populations,
- Integrate the wave models with the models of ring current dynamics that provide self-consistent global background electric and magnetic fields and realistic ion composition,
- Evaluate quasi-linear diffusion rates, based on the modeled wave properties, and determine whether the effects of non-linear scattering processes need to be included in the coupled models, and
- Utilize the new understanding of the plasma waves to improve the 3D and 4D transport codes to calculate the dynamic variability of the radiation belts.

Coupling of Interplanetary Energetic Particle Populations to the Earth's Magnetosphere, Ionosphere and Atmosphere

Target Description:

The transport of interplanetary energetic particle populations in geospace involves the complex interplay of the source population in interplanetary space, the state of solar wind-magnetosphere coupling, and the internal magnetic field configuration. Within geospace, these energetic particles are a hazard to satellites and to humans, and they are known to have important effects on atmospheric chemistry. This focused science topic includes theoretical, modeling and observational studies that quantify how the coupling of solar energetic particles (SEPs) and galactic cosmic rays (GCRs) to the Earth's magnetosphere, ionosphere, and atmosphere is affected by heliospheric structures and the time variation of the magnetospheric magnetic field, as controlled by lower energy populations in the Earth's magnetosphere.

Goals and Measures of Success:

The overall goal is to acquire a better understanding of SEP and GCR transport in the volume bounded roughly on the outside by the bow shock and on the inside by rigidity-dependent geomagnetic cutoff surfaces in the Earth's magnetosphere, extending down to the stratosphere in the polar regions.

Criteria for the success of this focus group include a) progress in the physical understanding of SEP and GCR access to the inner magnetosphere (causes, morphology, temporal variation), and b) improvement in the predictive capabilities of geospace models including ring current and substorm effects.

Success would be demonstrated by achieving the following objectives: 1) understanding observed variations in SEP and GCR fluxes at various locations within the inner magnetosphere, 2) acquiring the ability to model variations in SEP access caused by geomagnetic storms and substorms, 3) developing a coherent picture of geographic distributions of ionization during a SEP event, in order to enable correlation with atmospheric dynamics and chemistry.

This topic complements the work of focus groups that have investigated foundational topics such as solar wind plasma entry and transport in the magnetosphere, the effect of heliospheric structures on GCR and SEP transport, and the integration of kinetic effects into global models. A general measure of success will be how well this focus group builds on the results and products of earlier or ongoing teams and establishes links to investigations within the LWS sun-climate theme.

Types of Investigations:

- Explore the effects of solar wind-magnetosphere coupling, such as the location and rate of magnetic reconnection and solar wind dynamic pressure variations, on the magnetic cutoffs of solar energetic particles and galactic cosmic rays in the Earth's magnetosphere and other planetary magnetospheres,
- Examine the effects of time-varying SEP populations on access to Earth's magnetosphere,
- Study the effect of changes in the magnetic field configuration through the evolution of cold and hot magnetospheric particle populations (e.g., the ring current and the near-Earth plasmasheet) on the entry and transport of SEPs and GCRs,
- Determine the effects of temporally-varying SEP populations on the geographic distribution of particle ionization in the atmosphere, and

- Apply time-varying cutoff rigidity models (based on observations of solar proton access) to predictions of the access of less-well-instrumented heavy ions to the inner magnetosphere and corroborate these predictions with observations of single-event upsets.

What Factors Control the Highly Variable Intensity and Evolution of Solar Particle Events?

Target Description:

It is widely believed that the largest solar energetic particle (SEP) events are caused by CME-driven shock acceleration (although other processes may also contribute). However, observationally, the efficiency of this process appears to be highly variable. As an example, a 2001 study found more than a thousand-fold spread in the intensity of >20 MeV protons accelerated by CMEs of the same velocity. On the other hand, a 2004 statistical study suggested that CMEs that erupt soon after a previous CME from the same active region are much more efficient in accelerating particles than those erupting into a pristine environment. Evidently, once a large eruption occurs, coronal and interplanetary properties play a key role, along with CME properties, in determining how intense the SEP event will be. This could be due to a stronger turbulence level or a larger population of seed particles at the second shock; other suggested explanations include differences in the open and closed field-line geometry, or a lowering of the Alfven velocity, leading to the formation of a stronger shock. Among the additional factors that likely affect acceleration and transport efficiency are shock geometry, global IMF structure, connection longitude, proton-amplified Alfven waves, and streaming limits.

This FST is timely. First, there are ~100 cycle-23 SEP events in the available database with broad SEP and solar-wind/ICME coverage (ACE, Cluster, GOES, SAMPEX, SOHO, Ulysses and Wind), and excellent near-Earth CME and other imaging (SOHO, RHESSI, TRACE, Hinode). With experience from these events as a guide, it will be possible to take full advantage of new, multi-spacecraft data from STEREO and near-Earth assets.

For cycle-24 events there is a unique opportunity to make multi-point measurements of SEP, solar wind, and ICME properties, providing much greater detail on coronal/interplanetary initial conditions, and on the resulting longitudinal and temporal evolution of SEP events. In addition, for the first time, three-point CME imaging will provide higher precision and more detailed CME properties, along with multipoint coronal imaging. Finally, SDO will enable greatly improved capabilities to characterize they dynamic solar activity and its effects on the inner-heliosphere. Never before have such an array of distributed *in situ,* imaging, and modeling assets been available for this focused study.

Goals and Measures of Success:

The scientific goal of this FST is to identify the key properties that characterize when (a) SEP acceleration is efficient (large, intense events with rapid onsets) and when it is not (small, slowly developing events), and (b) to identify the conditions that facilitate efficient SEP radial and longitudinal transport; and develop a physical understanding of how these key properties function with theory, modeling, and simulations. The practical goal is to enable a forecaster, during the first 1-2 hours following an eruption, to use multi-point real-time data, knowledge of initial coronal and interplanetary conditions, models and experience to make more accurate predictions of how intense, long-lasting, and far-reaching the SEP event will (or will not) be. The goal here is *not* to predict how or when an active region will erupt.

The primary measures of success of this work would be quantifying and then improving our current ability to combine real-time data (CME, radio, X and gamma-ray, and other imaging) along with data on initial conditions (IMF, solar wind, magnetic configuration) to forecast, within the first 1-2 hours following an eruption, the resulting peak intensity, fluence, composition, spatial evolution, and duration of accelerated particles, including the possibility of a large shock-spike event, or the possibility of an early "all-clear" announcement.

Types of Investigations:

- Studies of the effect of preconditioning of the interplanetary medium on the characteristics of an ensuing SEP event (particularly multi-point studies),
- Studies of the solar source and CME characteristics of large SEP events to identify key properties governing the efficiency of SEP acceleration,
- Modeling and theoretical studies of SEP generation and radial/longitudinal transport, and
- Studies of the longitudinal variation of the characteristics of SEP events.

Jets in the Solar Atmosphere and their Effects in the Heliosphere

Target Description:

One of the most striking features of the solar atmosphere is that it exhibits jetting activity at all size scales and at all temperature regimes; in fact, the upper chromosphere may well be nothing more than a collection of spicules. Consequently, developing predictive models for the coupling of the chromosphere to corona requires a comprehensive understanding of the origins and dynamics of jets. Although ubiquitous in the chromosphere and transition region, often identified as "explosive events", jets are also commonly observed in X-rays, especially in coronal hole regions where they may be playing an important role in the origin and properties of the solar wind. SOHO and STEREO have revealed that polar jets can extend out to beyond a solar radius and are related to plumes, which are ubiquitous in coronal holes. Hence, a deep understanding of jets may also be critical for modeling the coupling of the corona to the wind. Jets have long been proposed as a possible mechanism by which both coronal loops and prominences gain their mass. Furthermore, the recent results from Hinode and other spectroscopic instruments indicate that jets may be playing a central role in coronal heating. In addition, they have also been suggested to be sites of particle acceleration. Physical models for their origin have been proposed and range from magnetic reconnection to wave pressure driven mass lifting, but the underlying mechanisms for jet acceleration are still widely debated.

The problem of solar jets is now ripe for a focused team attack. We now have unprecedented new data from SDO and STEREO, which allow us to study the complete thermal evolution of jet material from chromospheric to hot coronal temperatures and spatial evolution from the chromosphere out to the wind. One of the major mysteries of the recently discovered type II spicules by Hinode is that much more mass is observed to accelerate upward than to fall back down. The most likely explanation is that the mass heats up to temperatures outside the Hinode temperature range. SDO, with its extensive temperature coverage and high time resolution will be able to resolve the evolution of the jet material and, thereby, help determine the role of jets in coronal heating and in solar wind acceleration.

Goals and Measures of Success:

The goal of this FST is to advance our understanding of the origins, structure, and dynamics of chromospheric and coronal jets, their extension into the solar wind, and their role in accelerating charged particles. This Topic is focused on jets rather than on major dynamic events such as eruptive flares and CMEs; however, comparative studies of possible relationships between the jet phenomena and CMEs/eruptive flares would be appropriate to this Topic. The prime measure of success for this work would be the development of accurate models for the UV – X-ray emission from jets, their contribution to the mass and energy flux of both the closed field and the open field corona and wind, and for their role in particle acceleration.

Types of Investigations:

- Studies of the properties of chromospheric/coronal jets: their masses, velocities, magnetic field, temperature/density structure, and the time evolution of these quantities,
- Studies of the statistics of jets and their possible role in providing mass and energy to the corona and solar wind,
- Physical models of jet acceleration and heating, and studies of particle acceleration by jets, and
- Studies of the signatures in the solar wind of coronal jets and plumes and to what extent they determine the properties of the fast and slow winds.

Critical assessment of flux-transport dynamo models

Target Description:

The origin of solar activity lies below the photosphere in the internal flows that generate the magnetic field and determine the properties of the dynamo. Between these causative flows and their effects in the solar atmosphere and heliosphere lies a chain of physical processes and interfaces that are complex and far from understood. Many such processes have been studied in detail, but the connections between them are largely unexplored. We must advance our understanding of these couplings and incorporate them in improved physics-based models in order to make reliable forecasts of the solar activity cycle.

Subsurface magnetic field can be generated in the tachocline at the base of the convection zone, in the body of the convection zone, near the surface in a shear layer, and by turbulence. In flux-transport dynamo models, the interplay between the large-scale internal flows of differential rotation, meridional circulation, kinetic helicity, and turbulent magnetic diffusion results in the transport of magnetic flux and helicity within the convection zone and subsequent concentration of the field to the point that it becomes buoyant and emerges at the surface. Emerged magnetic flux is transported to the poles by random motions and meridional flow. Flux-transport dynamo models have achieved significant success, but some critical ingredients are poorly constrained below the surface and incompletely understood even at the surface. Questions that need to be investigated include:

- What is the nature of interior flows, and how do they determine the sunspot cycle period?
- Are subsurface flows from helioseismology consistent with observed flows in the photosphere?
- Is there a near-surface component to the large-scale dynamo?
- How is magnetic helicity generated and transported throughout the convection zone?
- How does the generation of kinetic and magnetic helicity below the photosphere affect the emergence and evolution of active regions?
- Do observed polar fields arise only from the surface transport of active-region fields?
- Are models of photospheric flux transport measurably improved by including subsurface flows or different models of turbulent magnetic diffusion?
- Can critical elements of the flux-transport dynamo picture be constrained through observations of other stars?

Goals and Measures of Success:

The goal of this FST is to better understand the coupled magnetic and kinematic processes in the solar interior, photosphere, and corona and to use this knowledge to improve the predictive potential of flux-transport dynamo models. Metrics of success include improved agreement between observed and modeled surface magnetic flux, flux-transport dynamo simulations that better incorporate helioseismically determined subsurface properties and therefore have fewer free parameters, and the ability to account for the observed range of cyclic behavior in solar-type stars.

With the recent launch of the Solar Dynamics Observatory, NASA will have a wealth of pertinent data necessary to address this FST; for example, HMI will provide high-degree helioseismology and simultaneous high-cadence vector magnetic field observations in the photosphere. The broad and systemic nature of the proposed research requires a coordinated approach that spans multiple areas of expertise but retains a focus on critical elements of the *solar* flux-transport dynamo picture.

Types of Investigations:

- Studies of the relationship between helioseismic inferences of internal flows and observed vector magnetic fields in the photosphere, including detailed analysis of polar field measurements,
- Studies of near-surface dynamos and magnetic field transport below the photosphere,
- MHD models of convective turbulence at various depths in the convection zone, including surface effects such as supergranular flows, to yield better estimates of turbulent magnetic diffusion for inclusion in flux transport models, and
- MHD studies of the generation and transport of magnetic helicity at various depths in the convection zone.
- Studies of solar-type stars focused on measurable properties that can constrain the solar flux-transport dynamo picture—e.g., cycle period, rotation rate, differential rotation, latitude distribution of activity, and asteroseismic properties.

III. Advanced Computational Capabilities for Exploration in Heliophysical Science (ACCEHS): Organization of a Grass-roots Initiative and Workshop

Background

Computational modeling, simulation, and data assimilation have been among the most important drivers of scientific discovery during the last three decades. This progress has been enabled by remarkable leaps in computing technologies, producing parallel computers of great power and speed. It is reasonable to anticipate a near-future transition from the present-day terascale systems to the petascale and beyond. These advances are stimulating the development of novel algorithms and high-performance computing software by interdisciplinary teams of physical scientists, applied mathematicians and computer scientists. These tools present transformative possibilities for heliophysics. They can be used in the design of flagship experiments and diagnostic instruments that explore new physical phenomena and as yet inaccessible physical domains and parameter ranges. Other such tools are critical in the efficient data assimilation and in the successful mining of very large data volumes assembled by current and near-future state-of-the-art observatories.

These developments call for urgent investments in developing a program on Advanced Computational Exploration that will enable us to take theory, modeling, and data assimilation and analysis to a new level. The heliophysics community is going through a phase of rapid and radical transformation with vast increases in the sophistication of instruments, data rates, archive volumes and usage, and is hampered in its progress by urgent needs for theoretical interpretations and predictions on complex, nonlinear systems of environments coupling the Sun's deep interior to planetary climate systems: we are posing questions at a level of detail that cannot be resolved by incremental modifications to legacy computer simulation codes. The effectiveness of our community-wide theory, modeling, and data assimilation and analysis efforts depend critically on the development and use of innovative numerical algorithms and high-performance computing practices that are sweeping across some other scientific disciplines. It is no longer enough for us to assume that the fruits of the efforts made by other science communities will naturally diffuse into heliophysics, and that this slow diffusion will be enough for the heliophysics community to meet the challenges of the future. What is urgently needed is an investment by NASA in critical Advanced Computational Exploration that will lead to the deployment of computational frameworks and a software infrastructure that can be used by the heliophysics community to making scientific breakthroughs.

Workshop:

To pursue this goal, the SC is taking a leading role in developing a community-wide initiative leading up to a Workshop in Boulder, August 16-18, 2010. The SC has organized Working Groups (WG) that will have responsibility for (1) Solar, (2) Interplanetary, (3) Magnetosphere, (4) Ionosphere-Thermosphere, and (5) Advanced Computation topics. Each WG is led by two/three coordinators and six to eight other members, and will have the responsibility to produce Draft Reports that will be posted online before the Workshop, and made available to the community for feedback. The purpose of the Draft Reports is to articulate approximately 3-5 issues of transformative potential in each of the topics identified above, and propose strategies and opportunities for solution based on Advanced Computational Exploration.

At the Workshop, presentations will be made on each of the topics above based on the contents of the Draft Reports, and the community-wide input obtained online as well as from the participants of the Workshop. A Final Report will be prepared by September 2010 for wide distribution to the community and to all the relevant funding agencies. While the Report will be submitted by the 2010 LWS SC to NASA, the Workshop will involve representation from NSF, DoD, and NOAA, all of which are represented on the 2010 LWS SC. The final product of the Workshop will be a concise report that will serve as the foundation for the program on ACCEHS.

For more details and updates, see the Workshop website:
http://www.hao.ucar.edu/ACCEHS/index.php

Membership of Working Groups:

1. Solar WG
Spiro Antiochos (NASA/GSFC) and Karel Schrijver (Lockheed Martin), *Coordinators*, William Abbett (UC-Berkeley), Fausto Cattaneo (University of Chicago), Philip Judge (HAO/NCAR), Jon Linker (Predictive Science), Mark Miesch (HAO), Daniel Mueller (ESA), Len Fisk (UM, Ann Arbor).

2. Interplanetary WG
Christina Cohen (Caltech), Joe Giacolone (University of Arizona), and Gary Zank (University of Alabama, Huntsville), *Coordinators*, Alex Lazarian (University of Wisconsin, Madison), Janet Luhmann (UC-Berkeley), Pete Riley (Predictive Science), Marco Velli (JPL).

3. Magnetosphere WG
Mark Moldwin (UM, Ann Arbor) and Terry Onsager (NOAA), *Coordinators*, Mary Hudson (Dartmouth College), Vania Jordanova (LANL), Yu Lin (Auburn University), Nick Omidi (Solana Scientific/UCSD), Joachim Raeder (UNH), Michael Wiltberger (NCAR)

4. Ionosphere-Thermosphere WG
Philip Erickson (MIT) and Joe Huba (NRL), *Coordinators*, Meers Oppenheim (BU), Robert Schunk (University of Utah), Aaron Ridley (UM, Ann Arbor), Hanli Liu (NCAR)

5. Advanced Computation WG
William Daughton (LANL) and Tamas Gombosi (UM, Ann Arbor), *Coordinators*, Luis Chacon (Oak Ridge National Laboratory), Kai Germaschewski (UNH), Michael Hesse (NASA/GSFC), Homa Karimabadi (SciberQuest).

IV. The Heliophysics Summer School: Going Forward

During the years 2006-2009, the Heliophysics Summer School was led by Deans Karel Schriver and George Siscoe, who achieved a remarkable feat: the editing of a book in three volumes, *Heliophysics I, II, and III*, published by Cambridge University Press. (Volume III is expected to be available around October 2010.) The references for the three volumes are:

http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521110617
http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521760515
http://www.cambridge.org/us/catalogue/catalogue.asp?isbn=9780521112949

Lecturers of the Summer School during the past three years have written the articles in these volumes.

The Summer School is going forward under the supervision of three new Deans: Amitava Bhattacharjee, Dana Longcope, and Jan Sojka. The theme for the 2010 School is "Space

Storms." The Lecturers, many of who have lectured in past Schools, will draw their lecture material primarily from *Heliophysics I and II*. For more details on the School and Lectures, see

http://www.vsp.ucar.edu/Heliophysics/summer-about-over.shtml

One of the new features introduced by the new Deans is a Recitation and Homework session on the day after each lecture, where students will discuss interactively solutions to a problem set. The Summer School has reached agreement with Cambridge University Press to have these problem sets posted online. The solutions will be password-protected, and will be made available to lecturers who teach from the textbooks at the Summer School (or at other institutions).