NASA Living with a Star (LWS) Targeted Research and Technology (TR&T) Steering Committee Report for 2008 - 2009

June 23, 2009

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1. Summary

This report documents the conclusions of the FY09 TR&T Steering Committee (TSC). The TSC initiated its proceeding with a telecon, next met with the general community at the TR&T Town Hall Meeting at the 2008 Fall AGU meeting, and then held three meetings in the DC area (02/18 – 02/19, 04/16 – 04/17, and 06/08 – 06/09, 2009) where essentially all members were in attendance either in person or via phone-in.

From these deliberations the TSC reached the following major conclusions, discussed in more detail in the body of this report:

1. A strategy for implementing four-year Focused Science Topic (FST) teams was determined and a new set of FSTs was selected for recommendation to NASA HQ (Section 2.).

2. In order to accelerate progress toward the Sun-Climate objective of LWS, the TSC formulated a new program, the Sun-Climate Theme described in Section 3.

3. Given that 6 Strategic Capabilities are now on-going, the TSC concluded that it would be best to wait until next year to consider new Strategic Capabilities.

4. A plan for a new PostDoctoral Program was discussed and approved and an announcement for this Program was prepared (Section 4.1). Strategies for encouraging the teaching of heliophysics were discussed and a possible program was proposed (Section 4.2).

5. The TSC concluded that the Independent Investigations element has not proven to be effective, and consequently, concluded that it be eliminated from the TRT&T NRA for, at least, this year (Section 5).

6. The TSC concluded that the Tools and Methods element needs more clarification in the NRA so that so that non-compliant proposals could be filtered out without requiring a full peer-committee review. The TSC also reviewed the effectiveness of this program in actually delivering tools and methods to the community (Section 6).

7. A new program for heliophysics computing laboratories was discussed and a white paper was drafted (Section 7).

2. Focused Science Topics

The TSC devoted a substantial fraction of its meetings to discussing the progress of the FST element of the TR&T and strategies for its improvement. Four issues dominated the discussion: the lack of sufficient proposals in the field of Sun-Climate, the duration of the of the FST teams, metrics for measuring success of the Teams, and selection of the 2009 FSTs. The first issue is dealt with in Section 3 below.

On the issue of duration, NASA HQ has received the feedback from many of the present and past Teams that 3 years is inadequate to accomplish a team investigation. It often takes a year for the team members to become familiar with each other's work and establish working collaborations. Furthermore, collaborative research between groups at different locations and in different disciplines – one of the goals of the FST element – will necessarily proceed slower than work within a single group. The TSC, therefore, concluded that the funding duration for the FST teams should, in general, be for up to four years, as was begun in the 2008 NRA.

In addition to enhancing collaborative science, extending the team duration to four years can have added programmatic benefits. An ongoing issue has been the determination of metrics of success for the FST teams. Within the first three months of its funding, each FST team is required to produce an integrated research plan with schedule, milestones, and deliverables. In principle, these can serve as success metrics for the teams, however, monitoring each team's progress during the course of its work requires far more personnel resources than are available to NASA HQ. There is no mechanism, at present, for rewarding or penalizing a team that achieves or fails to achieve the milestones and deliverables of its research plan.

The TSC concluded that an effective strategy for both evaluating and encouraging success would be to hold a review of each team near the end of its third year, and make the fourth year funding for each team member be contingent on progress toward the goals described in the integrated research plan. The procedure would be similar to that now in place for the Strategic Capabilities, whose final two years of funding is contingent on success in their third-year review. Since only five teams, or so, would be reviewed each year, a small community panel could conduct this team review. Such a review would provide the TR&T program with measures of success for the FST element. This strategy would also have the major benefit of strongly motivating individual team members to participate at team meetings and engage fully in the team's work. Given its benefits, the TSC concluded that this review procedure should be applied immediately, including to the 2008 teams that have recently been selected.

A persistent problem with the FST review process is that proposers do not include a description as to how they would collaborate with and enhance a Team effort, even though they are explicitly requested to include such a description in the present NRA. The TSC, therefore, concluded that the language in the NRA must be strengthened so that proposals without such a description are deemed to be non-compliant. The TSC recommends that language similar to the following be considered for this year's NRA.

In order to be compliant to this ROSES element, each proposal submitted must contain a section, entitled "Proposed Contributions to the Focus Team Effort" and identified in the proposal's table of contents. Failure to include this section will result in the proposal being judged non-compliant, and the proposal will be returned.

This section must include the following three items:

- *The relevance of the proposal to the scientific objectives of the Focused Topic*
- *The potential contributions (e.g., data sets, simulation results, novel understanding of physical mechanisms, etc.) from the proposed effort to the Focused Science Team's effort*
- *Metrics and milestones for determining the successful progress and outcome of the proposed research.*

Since each Focused Science Team has to produce a joint statement of work specifying its deliverables, success criteria, and milestones, the mandatory section described here can serve as a starting point for this SOW.

Finally, the TSC devoted considerable time selecting suggestions for the 2009 FSTs. The Committee used the community input from the TR&T website and from e-mails to the TSC as the primary basis for its selections. It should be noted that almost all of the recommended FSTs below were derived from this community-input list. This point demonstrates that the community suggestions are, indeed, effective and should provide strong encouragement to the community to continue its active involvement with the program.

2.1 Suggested Focused Science Topics for 2009

Note that the list below includes only topics that address the following three TR&T Strategic Goals as described in previous TSC Reports:

(Solar Storms) *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.*

(Near-Earth Radiation) *Deliver the understanding and modeling required for effective forecasting/specification of magnetospheric radiation and plasma environments.*

(Ionosphere-Thermosphere) *Deliver understanding and predictive models of upper atmospheric and ionospheric responses to changes in solar electromagnetic radiation, and to coupling above and below.*

The fourth Strategic Goal (Sun-Climate), is being addressed by the Focus Theme discussed in Section 3 below. Note also that the list below is NOT in any priority order.

Hemispheric Asymmetries in Solar Wind – Magnetosphere- ITM Coupling

Target description: Solar wind energy sources intercepted by the magnetosphere and processed/transmitted into the ionosphere-thermosphere-mesosphere (ITM) system produce different responses in the northern and southern hemispheres owing to a number of factors:

(1) Seasonal and diurnal variations of the geomagnetic dipole tilt influence how the solar wind drives the magnetosphere, and create large hemispheric differences of ionospheric electrical conductivities that impact the electrodynamic coupling and mass flow between the magnetosphere and ionosphere;

(2) Hemispherically asymmetric plasma convection, as well as energetic-particle access to the high-latitude magnetosphere and ionosphere, depend on the orientation of the interplanetary magnetic field (IMF);

(3) Hemispheric and longitudinal variations of the geomagnetic field, including the South Atlantic Anomaly, modulate how thermospheric winds and ionospheric electric fields transport plasma, and also affect geospace electrodynamics;

(4) Seasonal variations of the northern and southern atmospheres are different, including an annual variation of thermospheric density and composition much larger than that attributable solely to the varying Sun-Earth distance.

Observations show pronounced asymmetries, over and above those of seasonal effects, in electron densities, conductivities, neutral composition, energetic particle precipitation patterns, and auroral boundary locations. Recent studies of ionospheric storms point to different morphology patterns during the solstices in each hemisphere, again over and above those due to seasonal effects. There have been a number of recent developments to aeronomical observational capabilities of both the northern and, in particular, the southern hemisphere, as well as advancements in numerical model coupling between the magnetosphere and the ionosphere-thermosphere system. It is now possible to take a global, system-level view of geospace, both with simulations and with data, to address the unresolved issues of hemispherical asymmetries. Thus, it is timely to investigate whether the solar wind – magnetosphere – ITM coupling that drives storm-time effects might act in more subtle ways to ultimately account for the ambient annual asymmetry during non-storm solstice periods.

Goals and Measures of Success: The goal of this topic is to determine the manner in which solar and solar wind drivers interact with the geomagnetic field and the upper atmosphere to create hemispherically asymmetric responses within geospace. This information will be incorporated in physical models that are capable of reproducing the observed hemispheric asymmetries. Success will be measured by the accuracy with which the relative importance of different causes can be quantified and the accuracy with which the improved physical models are able to reproduce the observed asymmetries.

Types of Investigations:

- Data analysis and modeling of the solar wind, magnetosphere, ionosphere, and upper atmosphere, focusing on the similarities and differences between the hemispheres of geospace during various levels of solar and solar wind forcing and geomagnetic activity.
- Identification of relations between observed asymmetries and other parameters of the geospace system.
- Model development and testing with respect to the observed asymmetries.
- Creation of data and/or model products for easy comparison and utilization in other data or model studies examining hemispheric asymmetries.
- Applications of data assimilation to the development of predictive capabilities for the asymmetric Geospace system.

Determine the Behavior of the Plasmasphere and its Influence on the Ionosphere and Magnetosphere

Target description: The plasmasphere is the cold light ion plasma which fills the inner magnetosphere. It is connected to the underlying ionosphere along geomagnetic field lines, and is typically bounded by a plasmapause layer. This boundary is characterized by significant coupled dynamical variations and plasma wave / particle activity, driven by the overlap of cool dense plasma with hot, tenuous plasma. In general, the plasmasphere provides a reservoir that helps maintain the night-side ionosphere. It interacts with radiation-belt particles and with plasma waves to scatter energetic particles into the atmosphere. As such, the plasmasphere boundary layer and its evolution are critical for radiation-belt dynamics. The plasmasphere is also a significant contributor to total electron content and its large-scale variations, both of which directly affect transionospheric radio signals such as GPS. When magnetospheric sunward convection speeds up, the plasmasphere is drawn out into pronounced plumes that supply substantial amounts of plasma to the dayside reconnection region, changing its asymmetry, and loading the resultant boundary layer flows in ways that may influence global magnetospheric dynamics.

An improved understanding and description of plasmasphere and plasmapause behavior is required for significant cross-disciplinary advances across the entire coupled ionosphere-thermosphere-magnetosphere-heliosphere system. In particular, there is a timely community need to advance our ability to model coupled system responses and to predict plasmaspheric plasma distribution and motion both along and across the magnetic field as well as the plasma-wave environment. Coupled system effects of interest include subsonic and supersonic multi-species ion upflow events, their corresponding ionospheric electron density structures and enhanced radiation-belt particle losses, and particle-particle and wave-particle interactions leading to plasma heating and photoelectron transport. Observations of plasmaspheric behavior are available under a wide variety of conditions from various NASA missions, especially recently from IMAGE, and significant data also exists from ground-based instruments and integrated line-of-sight total electron content observations from GPS and other radio wave techniques. Models exist that simulate field-aligned multi-species plasma flows and energetics, as well as global plasmaspheric density and temperature, but many uncertainties remain.

Goals and measures of success: The goal of this FST is to produce improved descriptions of the plasmasphere and plasmapause and their dynamic variability. The primary measure of team success will be the ability to obtain agreement between observations and models of daily, seasonal, solar-cycle, and storm-time variability of plasmaspheric density, temperature, and composition, plasmapause location, and plasma-wave density. Other measures of success will be quantification of the influences of the plasmasphere on ionospheric electron density, total electron content, and on radiation-belt particle loss.

Types of Investigations:

- Analyses of in-situ and remotely sensed plasmaspheric electron densities to establish a three-dimensional, time-dependent picture of the behavior of the plasmasphere and plasmapause;
- First-principles modeling of plasmaspheric density, composition, and temperature that include particle filling and depletion processes and electrodynamic coupling with the ionosphere;
- Observational and modeling studies of plasma convection, plasmapause layer dynamics, and plasmaspheric plume formation and transport;
- Theoretical studies of interactions among cold plasma, photoelectrons, radiation-belt particles, and plasma waves relevant to plasmaspheric heating and pitch-angle scattering.

Plasma-Neutral Gas Coupling

Target Description: The coupling of ionized plasma to neutral material is a fundamental physical process of importance to many problems in heliophysics and astrophysics. It is a key to our understanding of magnetosphere-ionosphere-atmosphree interactions, of the solar chromosphere, and of prominences and spicules embedded in the corona, as well as our understanding of interstellar gas within the solar system, comets in the solar wind, and planetary satellites inside magnetospheres or exposed to the solar wind.

Heliospheric material spans enormous ranges in thermodynamic and magnetic conditions. Regimes of plasma dynamic beta, particle magnetization, and form of conductivity change dramatically between the base of the chromosphere or thermosphere and the corona and magnetosphere, respectively. Mixed plasma conditions occur at interface zones, such as the cool spicules ejected into the solar corona, or ionospheric plasma fountains. Coupling across interfaces is especially strong when a magnetic field linkage threads the transition: mass, momentum, and energy transfer are then highly efficient. Where ions are magnetized, ion-neutral collisions may be the dominant way to convert fast ordered motion into heat. This is a major source of heating for the ionosphere and thermosphere, and possibly for the chromosphere. If significant, this mechanism would place chromospheric UV emission (with its varying influence on the planets) on a firm physical basis. Weakly ionized material may also play a significant role in determining the hydromagnetic state in adjacent regions, such as the corona, as ion-neutral collisions modify the conductivity and magnetic field, and above the aurora, where heating has recently been found to greatly enhance densities. The role of plasma instabilities and irregularities in plasma-neutral coupling is likely to be important, but is not well understood. Plasma-neutral coupling is an area ripe for an inter-disciplinary initiative comparing first principles theory with both solar and ionospheric remote sensing and ionospheric *in situ* observations, and holds the potential to resolve diverse problems of heliophysics.

Goals and Measures of Success: The principal goals are (1) establish a cross-disciplinary collaboration between the solar, magnetosphere, and the ionosphere/thermosphere communities to resolve strategically important questions concerning the transition from a weakly ionized dense gas to a fully ionized tenuous plasma with the linkage of the electromagnetic field, (2) enhance our physical understanding of such a system, and (3) encourage chromospheric observations that quantify magnetic and thermal conditions in the chromosphere, in particular, observations with the new generation of spectropolarimetric instruments, and (4) improve numerical modeling of the coupling in both the chromosphere and the ionosphere-thermosphere. Measures of success include: (1) First-principles self-consistent numerical models of the chromosphere that describe available observations, (2) First-principles self-consistent numerical models that describe realistically the plasma-neutral interaction in the ionosphere-thermosphere, (3) Demonstrated understanding of heating rates produced by ion-neutral relative motions in magnetized regions. (4) Refinement of self-consistent numerical models of energetics in the ionospheric E region that incorporate the full range of ionosphere/thermosphere kinetic and wave effects.

Types of Investigations:

- Analytical and numerical investigations of chromospheric and ionospheric heating including plasma-neutral gas coupling.

- Observations and data analyses that provide critical information to test the predictions of models of chromospheric heating. Examples might include measuring the ordered motions and change in magnetic field through the chromosphere.

- Observations and data analyses that provide critical information to test the predictions of models of ionospheric heating and outflow into the magnetosphere.

- Theoretical investigations and numerical models that self-consistently describe and successfully predict the plasma, neutral wind, and electromagnetic field interactions, constrained by both solar and ionospheric observations.

Probing the Solar Dynamo Mechanism through the Solar-Stellar Connection.

Target Description: The solar dynamo is the driver of our variable heliosphere. After five decades of research, simplified models of the dynamo have reached a stage where forecasting has become a reality. Some forecast skill has been demonstrated in the flux-transport class of mean field dynamos, yet fundamental questions concerning mean field theory remain. Different simulations have led to very different predictions for the upcoming solar cycle, a result of our limited understanding of the dynamo mechanism(s). Predicting the solar dynamo is of practical significance, because it can yield predictions of average space weather on year-to-year time scales similar to seasonal forecasts of terrestrial weather, and the solar irradiance. Predictions on longer time scales are not yet feasible but are of considerable interest for climate change. It is unlikely that full MHD studies can be directly brought to bear on the global dynamo problem because of the prohibitively large range of scales required. Hence, we must look to improve our understanding of the solar dynamo, and the predictive capability of models, in other ways.

This focused science topic aims to use information gleaned from other Sun-like stars to obtain a better empirical understanding of the solar dynamo. Confronting the essential ingredients of solar models with relevant solar observations is of course important, and the great majority of LWS focus topics regarding dynamos reflect that priority. But models designed for the solar dynamo run the danger of being artificially tailored to the Sun alone. If a model really captures the essence of the solar dynamo, it should be able to reproduce the cyclic activity of other Sun-like stars. Decades of data on the cycle duration and amplitude of these stars are available from programs at Mount Wilson and Lowell Observatory, and from X-ray data archives. Magnetic activity data are also being obtained for important Southern stars. For some stars, data for starspot coverage, differential rotation, flares and CME-like eruptions also exist in the literature.

A confrontation between dynamo models and stellar data is timely not only because of the urgency of the solar problem, but because two current asteroseismology missions, CoRoT and Kepler, probe critical properties of large numbers of stars with unprecedented accuracy.

While much stellar data exist, such as radius, rotation rate, depth of convection zone, and differential rotation, asteroseismology offers an unprecedented opportunity to combine high quality basic stellar data with activity cycle data. Stellar dynamo models can for the first time be built to predict magnetic flux and its distribution over latitude as a function of time, in particular cycle length and amplitude, for comparison with activity cycle measurements.

It is well known that the Sun has gone through many low activity periods like the Maunder minimum, related loosely to the "Little Ice Age", yet current dynamo models have difficulty reproducing such global minima, let alone predicting them. A small class of very inactive low variability stars has been identified as possible Maunder minimum candidates. Finding more of these, and studying their properties, will shed light on the physical processes underlying global minima, and help dynamo modelers incorporate and simulate them.

Goals and Measures of Success: The overall goal is acquiring a better understanding of the physical ingredients of the solar dynamo, especially those that cause global activity minima, in order to improve the predictive capabilities of current dynamo models.

The criteria for success of this focus group are a) progress in the physical understanding of the dynamos of solar-type stars including the Sun, and b) improvement in the predictive capabilities of the models. Success would be demonstrated by achieving one or both of the following objectives: 1) From studies, simulations, and data analysis of solar-type stars based upon current solar paradigms, show how key characteristics of the dynamo cycle depend on basic stellar parameters. 2) Determine whether a trigger for global activity minima exists, and if so, what is this trigger.

Types of Investigations:

- Dynamo simulations for solar-type stars, calibrated by available observations on cycle periods and amplitudes, starspot evolution and differential rotation, stellar flare (and CME) activity.
- Observational studies to determine basic parameters for activity cycles of Sun-like stars from archival data and currently operating missions.
- Combined studies of stellar activity and asteroseismic data.
- Studies of Maunder-like minima in stars and in the Sun, both through dynamo modeling and analysis of pertinent stellar and solar data.
- A limited number of continued direct confrontations of critical elements of solar models with observations, such as of the surface and interior transport of magnetic flux.

Predict the Onset and Space Weather Impacts of Fast CMEs/Eruptive Flares

Target Description: It is now widely accepted that the energy for the most destructive forms of space weather, including strong SEP events and major geomagnetic storms, resides in the strongly sheared magnetic field of an active region filament channel. This energy is often released explosively in the form of a fast coronal mass ejection and/or eruptive flare. Although we can predict where such events will originate, we cannot yet predict when they will occur and the magnitude of the resulting space weather.

Consequently, the prediction of CME/flare onset and impact is one of the major objectives of the LWS program and is a prime focus for its missions.

There are two reasons why this problem is now ripe for a focused team attack. First, we will soon have unprecedented new data from the first LWS mission, SDO, which will deliver continuous high-resolution (spatial and temporal) observations of the vector magnetic field at the photosphere and of the resulting coronal dynamics. The combination of STEREO and SDO will allow us to measure the complete evolution of an explosive event, from its energy buildup at the Sun to its impacts at 1 AU. Second, we now have the capability to perform detailed 3D modeling of CMEs/flares for comparison with the observations. Given that the Sun is entering the rise to maximum, it is now time to address this outstanding problem of CME/flare onset and impact.

Goals and Measures of Success: The goal of this Focused Science Topic is to relate quantitatively solar structure and evolution to the onset of a CME/flare event and to the intensity of the space weather driven by this event. The prime measure of success for this work would be a substantial improvement in our ability to predict when a solar eruption leading to a CME will occur and to predict the evolution of the CME and its space weather consequences.

Types of Investigations:

- Studies of photospheric/chromospheric/coronal magnetic structure and evolution leading to CME/flare onset.
- Development and testing of models (theoretical and empirical) that predict the onset, initial velocity and density, and internal magnetic field of CMEs.
- Development and testing of models that predict the CME properties in interplanetary space to Earth, including the internal CME properties and the shock that is generated.
- Assessment of the data required to predict the initiation of CMEs and their properties, including an assessment of the limitations of different data types and the prioritization of data needed to predict CME initiation and properties.

Origin and Nature of the Slow Solar Wind, Associated Interplanetary Structures, and SEP Transport

Target Description: At all times, the heliosphere is filled with a combination of fast and slow solar winds. The fast solar wind, typically associated with speeds exceeding 600 km/s, originates primarily from coronal holes. It is also characterized by ion temperatures that far exceed electron temperatures in the inner corona, at least out to 10 R_S from the Sun, and by near photospheric-like composition. At least half of the time, however, a substantial fraction of the near-ecliptic solar wind that immerses the planets has characteristics that are distinct from the fast wind: its speed is typically < 500 km/s, and the ion temperature tends to be lower than the electron temperature in the inner corona.

Furthermore, its ionic and elemental composition is much more representative of closed magnetic structures (e.g. loops) in the corona. The properties of the slow solar wind are far more dynamic and variable than those of the fast solar wind. The slow solar wind is generally found in the vicinity of the heliospheric current sheet emanating from streamers at the Sun, especially at the time of solar minimum. However, the sources for this slow solar wind have not been clearly established. Near solar maximum, the slow solar wind may not even be spatially limited to the heliospheric current sheet.

Fast-moving solar energetic particles (SEPs) propagate from the corona into the heliosphere and, consequently, are highly effective remote probes of solar-heliospheric structures. As such, they add much to our investigation of the slow wind. Moreover, to increase our understanding of the origin of SEPs, which is a central goal of the LWS program, a better understanding of the nature of the coronal and heliospheric magnetic fields in slow wind regions is required. Thus, it is natural to study the physics of SEP transport concomitantly with studies of the origin and nature of the slow solar wind.

Goals and Measures of Success: The goal of this FST will be to develop an understanding of the physical processes in the solar corona and inner heliosphere that determine the origin of the slow solar wind, its coronal and interplanetary plasma and magnetic field dynamics and structure, and the transport of SEPs through the slow wind. Measures of success would be a substantial advance in our understanding of the slow solar wind, especially, its source(s) at the Sun, the physical reasons for its similarities and differences to the fast solar wind, the mechanism(s) responsible for its temporal variability, and the origin(s) of the observed plasma composition and magnetic structures. Another important measure of success would be an improvement in our ability to model the slow wind accurately and achieve better agreement between solar wind models and in situ data. Improvement in models for the propagation of SEPs from their solar sources into the inner heliosphere is another important measure of success for this FST.

Types of Investigations:

- Studies of coronal structure and plasma properties, especially composition, with the goal of determining the source regions of the slow wind.
- Studies of the in situ magnetic and plasma properties of the slow wind, especially composition or other properties that allow us to distinguish source regions unambiguously.
- Studies of the relative properties of the fast and slow wind, focusing on identifying the clearly distinctive differences between the two winds and providing insights into the physical origins for these differences.
- Studies of SEP transport in slow wind regions.
- Studies of how SEPs can be used to connect the slow wind to its coronal sources.
- Development of improved models for the solar wind, especially models and physics-based procedures that can be delivered to the CCMC.

- Development of theories, models, and data analysis tools in anticipation of Solar Orbiter and Solar Probe Plus.

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3. The Sun-Climate Strategic Goal

One of the four Strategic Goals of TR&T is the Sun-Climate Connection. This field of study has acquired increased urgency and importance in recent years with the realization by the Nation and the World of the possible harmful impact of global change on life and society. This realization has led to increased support by the Congress and Administration for Earth studies by NASA and other federal agencies. The TSC concluded, therefore, that it would be in the best interests of the TR&T program to place more emphasis on the Sun-Climate connection. It may be possible to leverage NASA's investment by developing partnerships with other agencies, such as the NSF or NOAA, that have on-going activities in this field.

Progress in this field has been severely hampered, however, by the lack of a sufficiently large science community for the focused team approach to be effective. For example, one of the 2008 focused science topics in the Sun-Climate field drew far too few proposals to permit the formation of a focus team on that topic. The TSC concluded that a new approach, described below, should be initiated in order to foster the growth of Sun-Climate studies.

Sun-Climate Theme

The LWS Sun-Climate strategic objective is 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."* This theme represents a new opportunity to foster cross-disciplinary investigations of connections between solar forcing and climate. Particular emphasis is placed on coupling of the upper and lower atmosphere and the processes responsible for transmitting solar variations to the Earth's surface where they can affect regional climate. Only investigations of sun-climate issues will be considered compliant with this theme; climate investigations that are not directly relevant to solar forcing are not being solicited. Atmospheric responses on time scales of seasons to millennia are of primary interest.

It is anticipated that this new TR&T program element will be solicited on an annual basis over the next several years. Rather than aiming science contributions at a focused science team, proposers will submit individual investigations that must explicitly describe how the proposed work will lead to progress in achieving the prioritized goal quoted above. Contributions from a solar and upper atmosphere perspective will likely be on equal footing with those from a lower atmosphere climate dynamics and chemistry perspective. Exchange among diverse research foci within the Sun-Climate Theme is expected to grow through regular meetings (initially once a year), and individual collaborations are strongly encouraged.

Thematic Description: Proposals submitted to the new Sun-Climate Theme will target processes by which solar radiative and particulate forcing can impact the Earth's climate. Solar activity variations clearly influence the upper atmosphere, but signals diminish toward the surface. Nevertheless, in some locations climate-related parameters such as the historical surface temperature or moisture records exhibit variations that appear to be related to the solar cycle. Two key issues must be addressed to make progress in quantifying the solar contribution to climate variability and change: (1) Observed decadal to centennial-scale climate signals throughout the atmosphere and at the surface must be categorized as either systematically related to solar activity changes or as spurious because of internal climate system variations on similar time scales. (2) The emphasis of solar impact studies in climate research must be broadened beyond mean radiative forcing to include both direct and indirect atmospheric impacts of spectral irradiance and particle precipitation variations over the full range of spatial and temporal scales.

The intent of this Sun-Climate Theme is to initiate cross-disciplinary research that will develop a more solid mechanistic understanding of pathways by which solar variability affects the various levels of the atmosphere, and how these effects are communicated toward the troposphere and surface where they modulate global and regional climate. It also targets the pathways by which ongoing climate change influences the atmospheric response to solar forcing, both directly and via upward coupling. Investigations that identify these processes and analyze variations over a wide range of time scales are necessary to reconcile observations and understanding of the natural modulation of climate by the Sun, and to delineate the Sun's role in regional climate variability and current climate change. This information is crucial for testing climate models that are used for regional climate change prediction. Thus, this program component solicits investigations that seek to define and quantify the solar-induced changes in a "whole atmosphere" approach, emphasizing downward and upward coupling between the upper and lower atmosphere.

Objectives and Metrics: The overall objective is to predict the climate response to solar variability on regional as well as global scales. Metrics will be gauged for a number of tasks: (1) Identifying and quantifying the relevant pathways by which solar forcing causes variability in climate parameters such as atmospheric temperature, circulation, and wave activity over a broad range of time scales; (2) Isolating the regional and global climate response to variations in these pathways; (3) Assessing the sensitivity of these pathways to long-term change in the troposphere and atmospheric composition; (4) Incorporating solar forcing effects into coupled chemistry climate models (CCMs) to produce verified simulations of these effects on atmospheric processes; (5) Testing and improving the predictive capabilities of the CCMs and Earth System Models with regard to solar-induced forcing. Also of interest is identifying the minimum specifications of vertical extent, resolution and process complexity that a lower atmosphere model would need in order to adequately simulate solar effects on surface climate and variability.

It is expected that numerical modeling, theory, data analysis and assimilation investigations will contribute to the Sun-Climate Theme, with studies addressing seasonal to millennial time scales. The following topics are examples of relevant areas of investigation; these are meant only to be illustrative, and are not all-inclusive:

- Quantify wintertime constituent transport from the thermosphere to the stratosphere, and any subsequent effects on the troposphere, to investigate the influence on these processes of solar particle variability.
- Quantify stratospheric ozone variations caused by solar irradiance variability, and the impacts of these variations on atmospheric circulation patterns.
- Explore the sensitivity of planetary-wave propagation and of large-scale circulation processes, such as the Brewer Dobson circulation, to solar variability.
- Develop and apply statistical procedures to climate data in order to quantify solar-variability signals on various time scales, tying these signals to radiative, chemical or dynamical processes.
- Determine what regional climate variability is systematically influenced by solar variability.
- Develop an assimilation of meteorological data from the troposphere up to the lower thermosphere to identify the impact of solar variations.
- Investigate the sensitivity of inter-hemispheric coupling to wave activity variations induced by solar variability.
- Evaluate the spectral detail necessary for proper treatment of the radiative and photochemical response to solar spectral variability.
- Identify the dominant processes by which galactic cosmic rays can influence climate, including impacts on cloud condensation nuclei and thus cloud cover and cloud radiative forcing as well as impacts on the global atmospheric electric circuit.
- Assess the influence of climate change on any of the above.

Note that this theme is ***not*** soliciting proposals for the development of solar irradiance proxies unless they are specifically focused on improving the treatment of atmospheric coupling. Furthermore, this theme does not address day-to-day weather variability, except as it may connect to longer-term changes in tropospheric and stratospheric climate.

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4. Infrastructure Building

One of the main challenges for achieving the goals of LWS is that they require research and modeling that cut across traditional discipline boundaries and that integrate the science of the Sun-Earth system. Consequently, the building of a community that is truly adept in the whole field of heliophysics has always been a prime element of the TR&T Program. The TSC discussed two strategies for this infrastructure building.

4.1 The LWS Postdoctoral Program

The TSC reviewed and approved a plan to initiate a new postdoctoral program as part of the infrastructure-building element of the TR&T. The goal of the program is to train a new generation of heliophysics researchers who will attain expertise that crosses discipline boundaries and who will be capable of attacking the systems-science problems that are so critical to the success of LWS. A postdoctoral program was recommended by the original SDT and has been supported by every TSC. NASA HQ is to be commended for identifying sufficient resources to start the program at this time.

The plan is to have four ongoing LWS fellows per year, funded for two-year terms. Consequently, two positions would be competed each year. The program would be run much like the NASA Postdoctoral Program (NPP). An announcement for the program was drafted by the TSC and is included below.

Applications are invited to a new postdoctoral fellowship program designed to train the next generation of researchers in the emerging field of heliophysics. The program is sponsored by the NASA Living With a Star (LWS) program and administered by the UCAR Visiting Scientist Programs office.

Heliophysics embraces all science aspects of the Sun-Earth connection, and includes many of the basic physical processes that are found in our solar system, the laboratory, and throughout the universe. These processes generally involve the interactions of ionized gases (plasmas) with gravitational and electro-magnetic (both radiation and DC) fields, and with neutral matter. The physical domain of interest ranges from deep inside the Sun to the Earth's upper atmosphere, to the magnetospheres of the other planets, and extends out to the boundary between the solar wind and interstellar medium. Within this broad science discipline, LWS is a program designed to develop the scientific understanding required for the Nation to address effectively those aspects of the Sun-Earth system that affect life and society. Detailed information on LWS, its science interests, programmatic structure, and space missions can be found at: http://lws.gsfc.nasa.gov.

Two major topics of focus for LWS are the science of space weather and of the Sun-climate connection. Preference will be given to applicants whose proposed research addresses one of these two foci; but any research program relevant to LWS will be considered. Since the goal of the LWS postdoctoral program is to train Sun-Earth ***system*** researchers, preference will also be given to research projects that cross the traditional heliophysics subdomains of the Sun, heliosphere, magnetosphere, and ionosphere/upper atmosphere.

In order to succeed at such cross-disciplinary research, the host institution and the mentoring scientists(s) will play critical roles. Consequently, applicants must select a host scientist, who must be different from the candidate's PhD advisor (preferably at a different institution), and coordinate a joint application with the host scientist and institution. Potential host scientists are required to submit letters of intent and vitaes as part of the selection process. Hosts are expected to mentor the fellow, provide a reasonable office environment, a workstation, and any other unique research costs associated with this fellowship. To assist possible applicants, a list of possible hosts may be found at: *http://www.vsp.ucar.edu/*.

Please note that this list is not exclusive. Any U.S. research institution, including universities, government centers, and profit or non-profit organizations may serve as a host institution.

Applicants to this postdoctoral program are expected to have had a PhD for no more than five years at the start of tenure. A LWS steering committee selects the fellows. Additional details about this program, including the selection criteria used by the steering committee may be found at: *http://www.vsp.ucar.edu/* .

Qualified scientists and hosts are encouraged to apply by sending the following materials to the UCAR Visiting Scientist Programs office:

Postdoctoral Applicants:

- Cover letter identifying the name of this program
- CV including publication list
- Names/contact information of four professional references (one from thesis advisor, but not from potential host). *See online reference requirements: www.vsp.ucar.edu*
- PhD dissertation abstract, including title.
- Titled project description, not to exceed five pages including figures and appendices (minimum 12 pt. type size). Proposals must describe actual research project. Applicants are expected to coordinate closely with host in writing proposal.
- Statement of relevance to the NASA Living with a Star program, not to exceed one page.

Host Applicants:

- Letter of intent to host applicant and plans for mentoring (2-page limit)
- CV including selected publications (1-page limit)
- List of current and pending research support, as for a TR&T proposal

US citizenship is not required for application to this Program, but the selected postdoctoral fellows must be hosted at a U.S. research institution. Appointed scientists are employees of UCAR. The two-year fellowships include a fixed annual salary and benefits: health & dental insurance, paid time off, paid holidays, mandatory participation in TIAA/CREF retirement fund, and life insurance. A relocation allowance is provided as well as an allowance for travel to scientific conferences and other support costs.

The deadline for applications is: October 1, 2009.

Appointments will be announced in early December. Applications must be submitted in electronic form and preferably .pdf, via email attachments sent to *vspapply.ucar.edu.*

Reference letters should also be sent electronically, but we will accept hard copy or fax. If unable to send electronically, send the old fashioned way to:

UCAR Visiting Scientist Programs
P.O. Box 3000
Boulder, CO 80307-3000 USA

Need more information? Call 303-497-8649, email: vspapply@ucar.edu, or visit website: http://www.vsp.ucar.edu

NASA Living With a Star, Heliophysics Division sponsors this program.

UCAR is an EE/AAE who values and encourages diversity in the workplace.

4.2 Heliophysics Curriculum Development

The TSC discussed the need for the development of a standard, coherent graduate-level curriculum for the training of heliophysics PhDs. At present, the discipline is taught more-or-less piecemeal at various universities. One strategy for developing such a curriculum is to build on the work of the Heliophysics Summer School that has been led by George Siscoe and Karel Schrijver. Since 2007, the NASA LWS Program through the UCAR Visitors Program has sponsored a summer school to foster the articulation and dissemination of the broad and interdisciplinary area of knowledge that has come to be known as heliophysics (see http://www.vsp.ucar.edu/HeliophysicsSummerSchool/)

This school has brought together students and senior scientists interacting with each other in the context of lectures, computational laboratories, and problem-solving sessions, and has produced three books, to be published by Cambridge University Press. The TSC commends George and Karel for their success with the Summer School and their dedicated effort in producing the books. It is likely that future summer schools will enhance the supporting material for these books and even add to this sequence of books. As discussed in the webpage cited above, the summer school has a dual aim: 1) to educate students and teachers in heliophysics as a coherent and integrated discipline, and 2) to produce textbooks that can be used as a resource for teaching in universities.

In order to carry out this program to fruition, the TSC proposes a pilot program for three years under which scientists at US Universities can apply for grants that will enable them to teach courses in heliophysics to advanced undergraduate and graduate students. A typical course should reflect the integrated, interdisciplinary perspectives that have motivated the Heliophysics Summer School, and should use the books produced by the School as a resource, but it is not required that these books be the exclusive source of teaching material for the course. Scientists who hold tenure-track as well as non-tenure-track faculty positions in universities will be eligible to apply as long as they can provide evidence that the course will be supported by the relevant academic department(s) within a university. Among the requirements of the grant will be the delivery of a report that will discuss the curriculum for the course(s), the number of students who took the course and their immediate trajectories with respect to heliophysics, and the role the grant played in the nurturing of heliophysics at the university. Given that the books are not yet published, it is premature to begin such a pilot program this year, but the TSC recommends that this issue be taken up by next year's TSC for possible inclusion in the 2010 NRA.

5. Independent Investigations

The original intent of this element was to enable the consideration of cutting-edge ideas that have a high level of both urgency and impact on LWS goals and objectives, but are not suitable for a focus science team investigation. The LWS program received a large number of proposal submissions in this category, but only a few met the criteria of timeliness and strategic impact. Of these, most were amenable to a focus team approach. Given the new resource requirements of initiating a 4 year focus-science team program, and establishing a new Sun-Climate theme, the TSC concludes that the Independent Investigations is no longer an effective investment of resources by either the TR&T or the science community. The number of Independent Investigations that the TR&T will be able to support in the future is simply too low to justify the large investment of both the program's and the community's time in the peer-review process. Consequently, the TSC recommends that, unless the funding level for the TR&T increases significantly, the Independent Investigations be eliminated as a TR&T ROSES element.

If the Independent Investigations element is eliminated, then for much of the community the primary proposal opportunity within TR&T will be to the Focus Science Topics element. We also note that, in the past, a few proposals were selected in the Independent Investigations element for Focus Science Topics of the previous year, but now proposers will have only one opportunity to submit to a particular Focus Science Topic. It is imperative, therefore, that the community has as much time as possible to prepare for this opportunity. The TSF recommends that the schedule for release of the TSC report and the amendment to the ROSES be moved up. The amendment to the ROSES with the selected FSTs may have to wait until the TR&T budget is completely decided, but the TSC schedule could be adjusted so that the TSC report can be released in April or March. This would provide the community with, at least, the list of possible FSTs for that year.

6. Tools and Methods

The TSC devoted considerable attention to evaluating the success of the Tools and Methods element and to devising procedures for making the element more effective. The goal of the element is to deliver to the LWS program products that may not, by themselves, constitute a science advance, but that would either enable science advances by the community at large, or that could lead to useful predictive capabilities. An essential requirement is that the tools/methods are to be useful to the broad community, not just to the developer of the tool/method.

In order to evaluate the program, the TSC requested information on the number of past awards, their type, and their success at delivering the tool/method. Chuck Goodrich and Mona Kessel from NASA HQ compiled the following table:

Solicitation Year	Total Awards	Tools & Methods	Data Sets	Science	Instrument Development
2003	11	6 (55%)	4 (36%)	1 (9%)	
2004	6	6 (100%)			
2005	12	8 (67%)	1 (8%)	2 (17%)	1 (8%)
2006	5	5 (100%)			
2007	5	2 (40%)	2 (40%)	1 (10%)	

Not shown are the data on the success of delivery. These data are still being compiled and will be included in the TR&T website in the Tools and Methods link. However, Goodrich had contacted most of the PIs of the completed investigations by the time of the last TSC meeting, and found that over 80% have delivered a tool or method to either the CCMC or to some archival repository. The next step would be to evaluate the actual usage of the tools/methods by the community, but the data on this usage are not easily collected. One simple procedure would be to simply keep track of the number of hits on the CCMC website to the Tools & Methods deposited there. The results so far, however, lend confidence that the element is, indeed, delivering products to the LWS program, and provide compelling support for maintaining this element within the TR&T.

As shown in the Table, a small but significant fraction of the selected investigations was for the development of a data set. In most cases, the data set was to be used in some empirical model or for some other specific application. The issue as to whether the development of a data set is appropriate to the Tools & Methods element was discussed by the TSC (and by previous TSCs). The TSC concluded that data sets generally should be funded by mission DA programs or by the VxO programs, not by the TR&T. However, the development of a particular data set that is to be used in a tool or method could be appropriate for the TR&T. The TSC concluded that the decision as to whether data set development is relevant to the TR&T should be left to the peer-review panel to decide on a case-by-case basis.

Although the Tools&Methods appears to have been quite successful, to date, the TSC has two concerns with this element. First, is the issue of the delivery site for the tool/method. Approximately 30% of the tools/methods have been delivered to websites run by the investigators rather than by NASA. There are clear advantages to developer websites, such as frequent updating of the tool/method. But for long-term availability to the community of TR&T funded capabilities, the TSC concludes that the tools/methods must also be delivered to a NASA site such as the CCMC, VxO's, solar soft repository, a mission site, etc.

The second concern involves the implementation of the Tools and Methods element. Too many of the submitted proposals, and as identified in the Table, a few of the selected proposals have been for science investigations rather than the development of an actual tool or method. This places an unacceptable burden on the community panels and on NASA HQ to weed out such proposals. The TSC concludes, therefore, that the following instructions be included in the NRA. First the proposals to the program should be limited to two year duration. Since these are not research investigations, but the construction of well-defined tools, two years should be sufficient to deliver a product to NASA. If further development work is warranted in order to enhance or extend the tool/method, then another proposal can be submitted at the end of the two year award.

Furthermore, to expedite evaluation of proposal compliance, the TSC concludes that the Proposal Summary that is submitted at the NSPIRES website must include explicit language stating the following:

<u>*Deliverable:*</u> What will be the tool or method?

<u>*Delivery Site:*</u> Where will it be delivered (e.g., CCMC, data center, mission site, etc.)?

<u>*Schedule:*</u> When will it be delivered?

<u>Proposals that do not include this information explicitly in the Proposal Summary will be deemed non-compliant and will not be reviewed.</u>

7. Heliophysics Computing Needs

It is clear that advanced computation is essential for the success of LWS. The development of first-principles based nowcasting and forecasting capabilities requires the ability to calculate the evolution of complex systems faster than real time. The Strategic Capabilities currently under development, for example, are primarily computational tools and rely heavily on the use of state-of-art computational methods and hardware. Of course, there are many basic physics problems that must be solved before we can develop a truly robust predictive capability for space weather and its effects, but translating the new knowledge delivered by the TR&T program into useful tools will require advances in our computational technology. It should be emphasized that this need for advanced computation is not unique to LWS, but cuts across all of heliophysics.

Karel Schrijver, who has written a white paper on the subject, brought the issue of advanced computational needs to the attention of the TSC. From its discussions, the TSC concluded that the topic is of such broad importance that it needs to be addressed by the Heliophysics Division, as a whole. A subgroup of the TSC, led by Amitava Bhattacharjee and including Karel Schrijver, was charged with producing a revised white paper with recommendations for the Division. This white paper, drafted by Bhattacharjee, is included below. The TSC concluded that the next step should be a community workshop, organized with the help of NASA HQ, that would refine the recommendations of the white paper and propose a concrete program strategy to NASA. The TSC recommends that a committee consisting of: Bhattarcharjee (Chair), Antiochos, Goodrich, and Liemohn, along with experts from the computational community, be formed to consider the next steps in pursuing the issue of advanced computation.

Scientific Discovery in Heliophysics through Advanced Computing Laboratories

(drafted by Amitava Bhattacharjee)

During the last two decades, enormous advances have occurred in computing technologies, producing distributed-memory parallel computers of great power and speed. Based on this history, it is reasonable to anticipate a future in which heterogeneous, multi-core processors will enable calculations that will make a transition from the terascale to the petascale and beyond. These anticipated advances are stimulating the development of novel algorithms and high-performance computing software by interdisciplinary teams of physical scientists, applied mathematicians and computer scientists that are powerful tools of scientific discovery across multiple disciplines. Scientific communities supported by DOE and NSF are using and developing further these computational tools with the objective of making transformative discoveries, building on the foundation of traditional theoretical modeling and experimental approaches, and enhancing very significantly the impact and scope of the science learned by traditional approaches. These tools are also being used extensively in the design of flagship experiments and diagnostic instruments that explore new physical phenomena and as yet inaccessible physical domains and parameter ranges.

These developments call for urgent investments by NASA in developing a program on Advanced Computing Laboratories that will be dedicated to pursuing transformative discoveries in heliophysics, and enable us to take the theory and modeling effort in our discipline 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 urgent needs for theoretical interpretations and predictions on complex, nonlinear systems of environments coupling the Sun's deep interior to planetary climate systems. Our understanding of the heliophysics domain has grown much deeper, and we are able to pose questions at a level of detail that cannot be resolved by incremental modifications to our legacy computer simulation codes. Indeed, the effectiveness of our community-wide theory and modeling efforts depend critically on the assimilation, 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 through heliophysics, and that this slow diffusion will be enough for the heliophysics community to meet the challenges of the future. While cooperation and collaboration with other communities will and should continue in the interdisciplinary world of scientific computing, the heliophysics community must become an integral part of that ecology because the effectiveness of innovative algorithms and high-performance computing software is application-specific. What is urgently needed is a critical investment by NASA in a few Advanced Computational Laboratories led by heliophysics scientists, working in collaboration with applied mathematicians and computer scientists, that will lead to the deployment of computational frameworks and a software infrastructure that can be used by the heliophysics community for numerical experiments dedicated to understanding and making breakthroughs in the science uncovered by our flagship missions, both current and future.

We propose that the effort consist of three elements (not necessarily weighted equally):

- *Scientific Challenge Computational Frameworks* --- research, development, and implementation of innovative mathematical models and computational algorithms in scientific simulation codes that can take full advantage of state-of-the-art multi-core computers to solve critical problems in heliophysics. Collaborations with applied mathematicians and computer scientists, who are actively involved in research with physical scientists and are able to contribute software that can optimize efficiencies and performance on high-end computers, are strongly encouraged.

- *Collaboratory Software Infrastructure* --- research, development, and implementation on networking technologies to link geographically separated researchers and move large data sets, and visualization tools for large observational or numerical datasets.

- *Recruitment and Training of a New Generation of Computational Heliophysicists* --- training a new generation of computational scientists who are able to assimilate innovative mathematical algorithms and high-performance computing practices to applications in heliophysics.

ACKNOWLEDGMENTS AND FURTHER REMARKS

The ideas mentioned above are not my own, but drawn from a variety of sources which are precursors to the program proposed here. I would like to acknowledge two Department of Energy Reports: the *Report on Scientific Discovery Through Advanced Computing* (2004), and *A Science-Based Case for Large-Scale Simulation* (2004). Stimulated by the white paper by Karel Schriver (2008), from which I quote directly, I have adapted some of the ideas in the reports mentioned above to heliospheric science, keeping in mind that the allocation of resources by NASA to such a project is likely not to be as large as in DOE or NSF. Even with relatively modest resources, the impact of such a program in NASA can be great in collaboration with communities supported by DOE, NSF, or DOD.