B.7 LIVING WITH A STAR TARGETED RESEARCH AND TECHNOLOGY

Amended May 31, 2006

This final version of Appendix B.7: Living With a Star Targeted Research and Technology replaces in its entirety the Draft version that was released with the ROSES-2006 NASA Research Announcement. The due dates for Notices of Intent to propose (NOIs) and proposals are changed. NOIs are due July 31, 2006. Proposals are due August 31, 2006.

1. Scope of Program

1.1 Overview

The goal of NASA's Living With a Star (LWS) program is to develop the scientific understanding needed for the United States to effectively address those aspects of the Heliophysics science that may affect life and society. The LWS Targeted Research and Technology (TR&T) program element solicits proposals leading to a physics-based understanding of the integral system linking the Sun to the Solar System both directly and via the heliosphere, planetary magnetospheres, and ionospheres. The TR&T program's objectives can be achieved by data analysis, theory, and modeling, and the development of tools and methods (e.g., software for data handling). LWS is a crosscutting initiative whose goals relate to all aspects of NASA's Mission, namely (and in no priority order):

- To pioneer the future in space exploration,

  LWS will develop the knowledge needed to provide advance-warning space environment predictions along the path of robotic and human exploration.

  LWS will quantify the physics, dynamics, and behavior of the Heliophysical system over the 11-year solar cycle.

- scientific discovery, and

  LWS will provide understanding of the effects of solar variability on terrestrial climate change and of the causes of solar and magnetospheric disturbances on the Earth's technology infrastructures.

  LWS will engage and motivate the public by supporting a lifetime of learning and discovery about the Sun and its effects on each element of the Solar System.

- aeronautics research

  LWS characterizes those aspects of the Earth's dynamic environment needed to design reliable electronic subsystems for use in air and space transportation systems.

The *Final Report of the LWS TR&T Science Definition Team (SDT)* (December 2003), located on the LWS TR&T homepage at http://lws-trt.gsfc.nasa.gov/trt_resources.htm, identified TR&T as a systematic, goal-oriented research program. The TR&T component of the LWS program provides the theory, modeling, and data analysis necessary to enable an integrated system-wide picture of Heliophysics science with emphasis on societal relevance.[1]

Significant progress toward quantitative understanding and predictive capability with respect to these problems will require large-scale, integrated modeling activities. Recognizing the need for activities that would be broader and more sustained than those that can be supported by a traditional NASA grants program, the *Final Report of the LWS TR&T Science Definition Team* recommended that "…large modeling activities that address coupling across traditional science domains in the Sun-Earth chain specifically be included as strategic capabilities." The TR&T SDT also recommended the formation of a TR&T Steering Committee in order to update periodically the designated strategic capabilities for future NRAs. The most recent report of this Steering Committee is available on the LWS TR&T homepage at the address given above.

As a result of these studies and recommendations, the LWS TR&T program has defined a strategy with three program elements, namely, Strategic Capabilities, Targeted Investigations, and Cross-Disciplinary Infrastructure Building programs. This current solicitation requests proposals only for the last two of these program elements as discussed in the following subsections. A separate solicitation will be issued in 2006 at least 90 days prior to the proposal due date soliciting proposals on Strategic Capabilities (see Appendix B.8).

Further background material concerning relevant research objectives can be found in the following documents:

- The National Academy of Sciences Web tutorial, entitled "*Space Weather: A Research Perspective*" (http://www7.national-academies.org/ssb/SSB_Space_weather97.pdf);
- The Sun Earth Connection LWS web site (http://lws.gsfc.nasa.gov/);
- The LWS Science Architecture Team report to SECAS (http://lws.gsfc.nasa.gov/documents/sat/sat_report2.pdf);
- *The Sun-Earth Connection Roadmap Report* (http://sec.gsfc.nasa.gov/sec_2002_roadmap.pdf);
- *The NRC Decadal Survey Report* (http://www.nap.edu/books/0309089727/html/);
- *The Heliophysics Roadmap* (http://heliophysics.gsfc.nasa.gov/sec_roadmap.htm);
- *The TR&T Science Definition Team Report* (http://lws-trt.gsfc.nasa.gov/TRT_SDT_Report.pdf); and
- *The TR&T Steering Committee Team Report* http://lws-trt.gsfc.nasa.gov/trt_resources.htm).

[1] Heliophysics: To understand and predict the causes of space weather by studying the Sun, the heliosphere, and the planetary environment as a single connected system.

1.2 Targeted Investigations

This Targeted Investigations program element is subdivided into the three components described below and, pending the submission of proposals of adequate merit, the approximate portion of resources allocated for each is given in parentheses.

1.2.1 Tools and Methods

The Tools and Methods component supports studies that, by themselves, may not deliver significant new science understanding, but instead deliver tools and/or methods that enable critically needed science advances. Examples include the development of new empirical methods or analysis techniques, such as local helioseismology, that can be used to forecast solar, interplanetary, and geospace activity, and the development of software tools that can identify, retrieve, assimilate, and/or portray data in order to model results from different sources for LWS research and forecasting objectives. Some more examples of tools and methods investigations can be found in the "Feedback from Community" at http://lws-trt.gsfc.nasa.gov/trt_resources.htm.

1.2.2 Independent Investigations

The Independent Investigations component supports studies that are not appropriate for either the Tools and Methods component above or the Focused Science Targets component discussed in the next section. However, simply failing to address these other two components does not necessarily make a project suitable for this Independent Investigations component. Rather, the criteria that determine whether a proposed study should be submitted to this component are its urgency and impact to LWS goals and objectives. Some examples of independent science investigations can be found in the "Feedback from Community" at http://lws-trt.gsfc.nasa.gov/trt_resources.htm.

1.2.3. Focused Science Topics

The stated goal of LWS, that of achieving an understanding of those aspects of the Sun-Solar System that have direct impact on life and society, poses two great challenges for the TR&T program. First, the TR&T must tackle large-scale problems that cross discipline and technique (e.g., data analysis, theory, modeling, etc.) boundaries; and second, the TR&T must identify how this new understanding will have a direct impact on life and society. To address these requirements, a set of five Focused Science Topics as further identified below have been chosen for emphasis in this solicitation (for further detail, also see the TR&T Steering Committee Report at http://lws-trt.gsfc.nasa.gov/trt_resources.htm). Therefore, while the primary evaluation criteria remain unchanged (see this NRA's *Summary of Solicitation*, Section V(a), and the *NASA Guidebook for Proposers*, Appendix C.2), the criterion for relevance includes relevance to one of these five Focused Science Topics as an essential requirement for selection within this component. In addition, NASA desires a balance of research investigation techniques for each Topic, including theory, modeling, data analysis, observations, and simulations. Given the submission of proposals of adequate number and

merit, up to eight selections will be made for each Focused Science Topic. Once selected, these investigators will form a team in order to coordinate their research programs (similar to the PIs selected for a NASA hardware mission who form a coordinated science working group). These teams will define a plan for structuring their work into an integrated research program that ideally will address the Focused Science Topic in a much more complete way than any one investigation could by itself. These teams will also define success measures and deliverables for their integrated program, develop strategies for disseminating their results to the science community and NASA, and prepare an integrated final Team Report at the end of the three-year duration of the selected investigations.

Based in part on the peer review, one of the PIs will be identified and asked to serve as the Team Coordinator for the Focused Science Topic for which he/she proposed. These Team Coordinators will take the lead role in organizing their teams, setting up appropriate meetings and interactions, and generally ensuring the success of the project as a whole. The Team Coordinators will also serve as the lead liaison with the LWS Project Office at NASA's Goddard Space Flight Center (GSFC) and LWS Program Office at NASA Headquarters, which together will monitor and assist the progress of each team. The Team Coordinator will receive supplemental funding as necessary to support costs associated with these duties. Proposers are encouraged to propose to act as a Team Coordinator and if they do so, should include a brief section in their proposal describing how they would lead the team effort. Up to one extra page in the proposal is allowed for this proposed effort. All proposers for Focused Science Topics should include sufficient travel funds in their proposed budgets to cover two team meetings per year to be held on the U.S. coast furthest from their home institutions. This NRA solicits four Focus Topics related to TR&T and one Focus Topic related to Solar Sentinel Mission's science objectives.

The Focused Science Topics appropriate as the objectives for proposals to this LWS TR&T solicitation are as follows:

a. Investigate the Global Distribution, Sources and Effects of Large Electron Density Gradients at Middle and Low Latitudes

Target description: Large electron density gradients in the middle and low latitude ionosphere have a major impact on a variety of technological systems, including navigation, communications, and radar. Recent methods for imaging ionospheric electron density structure using ground-based and space-borne instruments are providing a new observational context for measurements that capture these gradients. Understanding the physical causes of large gradients often requires a "systems-level perspective" of the coupled Sun-Earth system, involving solar-wind, magnetospheric, ionospheric, and thermospheric processes. The interaction of these various physical systems to create the ionospheric features of such major societal impact represents an important frontier of scientific knowledge and will require imaginative new methods, models, and combinations of data to understand and predict. The focus of this topic is middle to low latitudes regions (broadly defined) where technological systems are concentrated.

Goals and measures of success: The goal of soliciting these investigations is to produce an improved scientific understanding and characterization of large electron density gradients in the Earth's middle and low latitude ionosphere, leading to improved models that can generate predictions of societal value. We expect to produce a better characterization of the temporal and spatial scales, magnitudes, and global distribution of large gradients, under what conditions they form, and the physical understanding necessary to model such features as a function of the geophysical conditions that create them. Improved prediction capability should be established.

Types of solicited investigations: Proposals that address this topic are expected to exploit observational, theoretical, and modeling approaches that improve characterization and scientific understanding of large electron density gradients in the middle and low latitude ionosphere. The research objectives can address one or more of the following areas: 1) improved characterization of the global distribution, dynamics, and lifetimes of large gradient features; 2) theoretical analyses that elucidate how they are generated and related to conditions in the broader geophysical environment; 3) model development of appropriate spatial and temporal resolution to simulate the relevant physical processes; and 4) establishing new empirical or theoretical relationships that will lead to improved modeling and prediction. It is expected that a significant number of submitted proposals will deal with cross-disciplinary topics involving observations and modeling of solar wind, magnetospheric, ionospheric, and thermospheric coupled processes.

b. Effects of Ionospheric-Magnetospheric Plasma Redistribution on Storms

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

Goals and measures of success: The goal for this topic is to establish how the magnetospheric uptake of ionospheric plasma during storms changes as a result of plasma restructuring, and how this uptake influences the dynamics and coupling of the magnetosphere and ionosphere, with emphasis on the plasma and geomagnetic field conditions of the inner magnetosphere and the evolution of the ionospheric conductance, temperature and densities. Measures of success include the identification of principal mechanistic features and quantitative assessment of their impacts over the range of stormtime conditions and solar wind and IMF drivers.

Types of solicited investigations: Team efforts optimally would encompass complementary theoretical analysis, observational and empirical approaches, both ground-based and *in situ*, and large-scale modeling of the ionosphere and magnetosphere. Nonexclusive topics of interest include: specification and forecasting of plasmasheet and ring current ion composition, energy, and distribution for stormtime solar, ionospheric, and magnetospheric conditions; distribution and rate of magnetospheric intake of ionospheric and plasmaspheric ions during storm conditions; impacts of stormtime ionospheric plasma redistribution on magnetosphere-ionosphere coupling; and energization, transport and loss of ionospheric ions in the magnetosphere.

c. Predict Emergence of Solar Active Regions Before they are Visible

Target description: A major roadblock for predictive models of space-weather effects has been our inability to forecast the emergence and evolution of large active regions on the Sun. Recent developments in the field of helioseismology show promise for the detection of active regions that emerge and grow on the far side of the Sun, and for the detection of preemergence signatures on the front side that may be measurable with several different techniques. This research area has obvious importance for improved space-weather modeling, and predictions of the structure of the corona and the heliosphere. Research in this area will greatly enhance the usefulness of the SOLAR-B and SDO missions.

Goals and measures of success: The goal of this Focused Science Topic is to develop, test, and refine techniques for the detection of active regions before they are visible, the exploration of techniques to determine whether preemergent or newly emerged active regions will grow and become flare-productive, and to explore how such knowledge could be incorporated into downstream predictive models of the outer corona and heliosphere. The prime measure of success for this work will be to demonstrate a statistically significant ability to predict the location of new active regions before they are visible on the surface of the Sun and also their evolution.

Types of Solicited Investigations: It is expected that the focus team will include, but not be limited to, the following types of investigations: The improvement of helioseismic techniques for far side imaging of active regions; the refinement and testing of helioseismic techniques for detecting active regions on the front side of the Sun before they are visible on the surface, and for detecting signatures of developing flare-productive active regions; collaborative research between helioseismologists and solar interior modelers on the behavior of magnetic fields and flows expected in pre-emergent and growing active regions; and the development of techniques to quantitatively assess the predicted impact of a specific newly emerged active region on the global structure of the corona and heliosphere.

d. Solar Origins of Irradiance Variations

Target Description Solar irradiance is the dominant driver of Earth climate. The variations in this fundamental parameter which are best known are the cyclic changes in

total solar irradiance (TSI). In recent years continuous records of fluctuations in spectral irradiance have also been acquired. These data are now being incorporated in Earth-atmosphere models that include the absorption of different wavelengths of solar irradiation in different atmospheric layers and their coupling to fundamental modes of atmospheric oscillation. The variable solar soft X-ray, EUV, and coronal X-ray emissions play a dominant role in controlling the thermodynamics, chemistry, and ionization state of the terrestrial upper atmosphere, and are largely responsible for the most severe space weather impacts affecting telecommunications and satellite drag.

Progress in nowcasting and forecasting the solar spectrum depends critically on the availability of realistic, physics-based models of the solar activity affecting irradiance. Both total and spectral irradiance variations have been associated with manifestations of solar activity since the availability of the first space-borne measurements of these parameters, but less has been done to understand the physical processes by which solar activity causes these variations. Improved understanding of the detailed properties of solar active regions and solar impulsive events will allow the construction of models that describe the spectrum of the radiation emitted from the Sun under different conditions, and thus indicate where in the terrestrial atmosphere the radiant energies will be deposited.

Goals and Measures of Success: The goals of this Focused Science Topic are to understand how spectral irradiance variations from the Sun are produced and, in particular, to understand the physical processes causing variations in the solar spectral emissions. The prime measure of success for this work would be a substantial improvement in our ability to reproduce multi-spectral observations of active regions using physics-based models.

Types of Solicited Investigations It is expected that the focus team will include investigations to model active regions based on first principles; predict the dependence of solar spectral irradiance on key physical parameters such as magnetic topology, field strength, loop length, and velocity patterns; and give a relationship between active region evolution and changes in the solar radiation spectrum.

e. Understand how Flares Accelerate Particles near the Sun (i.e., through Shocks and/or Reconnection) and how they Contribute to Large SEP Events

Target description: Recent studies have shown that energetic particles accelerated during solar flares could make direct and significant contributions above tens of MeV during some large SEP events observed at Earth. However, the basic mechanisms by which particles are accelerated to such high energies in flares are not well understood. Uncertainties in comparing the timing of various forms of solar activity, as well as scattering uncertainties in the inner heliosphere, has made it difficult to assess the relative contribution of flares to any given large SEP event. To understand and predict solar particle radiation near the Earth and in the heliosphere requires a cross-disciplinary approach from the solar and heliospheric communities. Specifically, it is necessary to

utilize remote and *in situ* observations of solar flares and SEP events to test and improve existing analytic and numerical models of particle acceleration in solar flares.

Goals and measures of success: The goal of this topic is to combine theoretical studies, numerical simulations, and remote and *in situ* observations to understand the basic mechanisms by which particles are accelerated to >50 MeV energy in solar flares. The measure of success, and the criterion for proposal selection, is the potential impact of the work in quantifying the limits of various particle mechanisms (e.g, magnetic reconnection, parallel electric-fields, shocks, second-order Fermi acceleration, etc.,), and in determining if the flare-accelerated ions could also make direct and significant contributions to the large gradual SEP events observed at Earth.

Types of solicited investigations: Proposals that contribute to our fundamental understanding of the energization and escape of particles accelerated during solar flares using either observations or theoretical analysis are encouraged. Observational studies that seek to characterize the solar origin and key properties (e.g., ion composition, electron association, electromagnetic emission) of SEP events at Earth using remote and *in situ* measurements are also relevant. Analytical and numerical models that seek to predict the energy extent, the observed ion composition i.e., the enhancements in ^{3}He, heavy and ultra-heavy ions, and the associated spectral forms, are also encouraged. Proposals that seek to quantitatively test the predictions of various numerical and analytical models and determine the relative contributions of flare-accelerated ions to large gradual SEP events are highly relevant. Proposals that combine existing datasets or numerical models with relevant datasets from upcoming missions like STEREO, SDO, and Solar-B are also encouraged. All proposals should specifically address how they will enhance future measurements outlined in the LWS Solar Sentinels Science and Technology Definition Team Report which will be posted on the LWS TR&T homepage at http://lws-trt.gsfc.nasa.gov/trt_resources.htm on or about June 15, 2006.

1.3 Cross-Discipline Infrastructure Building Programs

One of the major challenges facing the LWS program is the development of a research community that can cross traditional discipline boundaries and attack the system-wide problems that are central to understanding and modeling the Sun-Solar System connection. In order to address this challenge, proposals to this LWS TR&T program may include one or more of these infrastructure-building elements: cross-disciplinary workshops, and/or summer schools. Most of these activities will be supported through formal proposals to the TR&T as part of the regular proposal cycle. In all cases, an extra two pages will be allowed to the page limit for the Science/Technical/Management section of the proposal (see the *NASA Guidebook for Proposers* discussed below) for each of these activities.

a. Support of LWS Workshops/Campaigns: Given the goals of the Infrastructure Building Program, there are several guidelines that successful requests for *workshop/campaign* support must satisfy:

1. The workshop must address a science or technology topic that is both timely and important to the goals of LWS.
2. The workshop topic must be cross-disciplinary in nature and bring together researchers from different disciplines in LWS science.
3. Although there are no restrictions as to where the workshop will be held, it will clearly be advantageous to hold it at a location that is convenient and cost-effective for LWS researchers and students.
4. Workshops that encourage the training of new researchers in LWS system science are strongly encouraged.
5. Workshops that leverage funding from other institutions and agencies are strongly encouraged.

b. Support of LWS Summer Schools for Graduate Students: The details of the summer school (e.g., format, location, duration, etc.) are left to the proposer to define. However, proposals should provide convincing evidence concerning the breadth of the topics to be considered, the means to be taken to assure participation by recognized research/education authorities, and any institutional support that may be forthcoming (note: shared support of this activity is strongly encouraged). One such proposal may be selected for summer school activities not to exceed more than two years during the nominal three-year period of performance for the parent research proposal.

2. Programmatic Information

2.1 Demonstration of Relevance to LWS Objectives

Proposers are reminded that the evaluation criteria for this solicitation are given in the *NASA Guidebook for Proposers* (see below for reference). These criteria are intrinsic merit, relevance to NASA's strategic goals and objectives, and cost realism and reasonableness. In addition to the factors given in the *NASA Guidebook for Proposers*, the evaluation criterion "intrinsic merit" specifically includes the following factor:

- Proposals will be evaluated on the basis of their feasibility, intrinsic scientific merit, and compliance with requirements to provide public access to any tools and value-added products developed. Proposals should provide a detailed (~1/2 page) description of how the proposed work will benefit the goals and objectives of the LWS program described above, and the timetable over which these benefits will accrue. To this end, the LWS program will provide a web site (http://lwstrt.gsfc.nasa.gov/trt_proposals.htm) that provides links to the abstracts of all selected proposals and their annual progress reports, including developed and tested software and/or refined data products.

In addition to the factors given in the *NASA Guidebook for Proposers*, the evaluation criterion "relevance to NASA's strategic goals and objectives" specifically includes the following factor:

- The degree to which the proposed investigation is relevant to one of the five Focused Science Topics described in Section 1.2.3.

To aid in the identification of reviewers, it is essential that the electronically submitted *Cover Page* for LWS TR&T proposals (see further below) include a single choice of program descriptor (i.e., T for Targeted Research or C for Cross Discipline Infrastructure) and the relevant program objective under each descriptor as follows:

- T1 -- Tools and Methods,
- T2 -- Independent Investigations,
- T3a – Electron Density Gradients in Ionosphere,
- T3b --Ionosphere-Magnetosphere Plasma Redistribution,
- T3c –Emergence of Solar Active Regions,
- T3d –Solar Origins of Irradiance Variations, or
- T3e –Particle Acceleration Near the Sun.

In addition, each proposal may additionally include one or more of the following descriptors as appropriate:

- C1 -- Workshop/Campaign, and/or
- C2 -- Summer School

Therefore, a proposal for Particle Acceleration Near the Sun that includes provisions for both a summer school as well as a Workshop would be labeled "T3d-C1-C2".

2.2 Summary of Key Information

Expected annual program budget for new awards	~ $5 M
Number of new awards pending adequate proposals of merit	~ 40
Maximum duration of awards	3 years
Due date for Notice of Intent to propose (NOI)	July 31, 2006
Due date for proposals	August 31, 2006
NASA strategic objective(s) which proposals must state and demonstrate relevance to	Every proposal must address one or more strategic goal or strategic outcome from Table 1. See also Sections I(a) and IV(e) in the *Summary of Solicitation* of this NRA.
General information and overview of this solicitation	See the *Summary of Solicitation* of this NRA.
Detailed instructions for the preparation and submission of proposals	See the *NASA Guidebook for Proposers Responding to a NASA Research Announcement – 2006* at http://www.hq.nasa.gov/office/procurement/nragu

	idebook/.
Page limit for the central Science-Technical-Management section of proposal	15 pp; see also Chapter 2 of the *Guidebook for Proposers*
Submission medium	Electronic proposal submission is required; no hard copy is required. See also Section IV in the *Summary of Solicitation* of this NRA and Chapter 3 of the *NASA Guidebook for Proposers*.
Web site for submission of proposal via NSPIRES	http://nspires.nasaprs.com/ (help desk available at nspires-help@nasaprs.com or (202) 479-9376)
Web site for submission of proposal via Grants.gov	http://grants.gov (help desk available at support@grants.gov or (800) 518-4726)
Funding opportunity number for downloading an application package from Grants.gov	NNH06ZDA001N-LWS
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