B.6 LIVING WITH A STAR TARGETED RESEARCH AND TECHNOLOGY

Amended July 21, 2008

This final version of Appendix B.6: Living With a Star Targeted Research and Technology replaces in its entirety the Draft version that was released with the ROSES-2008 NASA Research Announcement. The due dates remain the same. Notices of Intent to propose are due September 19, 2008. Proposals are due October 17, 2008.

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 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 strategic goals relate to all aspects of NASA's Mission, namely (in no priority order):

1. Solar energetic particles and galactic cosmic rays pose major radiation hazards for space hardware and astronauts. Penetrating particle radiation adversely affects aircraft avionics and, potentially, the health of airline crews and passengers on polar flights. Communication and navigation systems are directly affected by impulsive changes in the solar particle and electromagnetic output leading to rerouted polar flights and GPS outages. In support of U.S. Space Exploration Policy and the national communication, navigation, and transportation infrastructure, the TR&T program needs to deliver the understanding and modeling required for useful prediction of the variable solar particulate and radiative environment at the Earth, Moon, Mars, and throughout the solar system.

2. One of the major challenges facing humanity is global climate change. In order to gauge the response of the terrestrial climate system to natural and anthropogenic forcings, NASA, through the TR&T program and Earth Science Division, in conjunction with other national agencies such as the National Oceanographic and Atmospheric Administration (NOAA) and the National Science Foundation (NSF), needs to deliver the understanding of how and to what degree variations in the solar radiative and particulate output contribute to changes in global and regional climate over a wide range of time scales.

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

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

These strategic goals and the selection of strategic capabilities will guide the selection of focused science topics for this solicitation. The primary goal of the LWS Program is to make progress in understanding this complex system, focusing on the most critical interconnections.

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.

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 solicitations. The most recent report of this Steering Committee is available on the LWS TR&T homepage at http://lws-trt.gsfc.nasa.gov/.

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. 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 *The Sun to the Earth and Beyond* (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 latest TR&T Steering Committee Team Report* (http://lws-trt.gsfc.nasa.gov/trt_resources.htm).

1.2 Targeted Investigations

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 program must tackle large-scale problems that cross discipline and technique boundaries (e.g., data analysis, theory, modeling, etc.); and second, the TR&T program must identify how this new understanding will have a direct impact on life and society.

This Targeted Investigations program element is subdivided into the three components described below: As a goal, approximately 80% of the allocated resources will be spent on Focused Science Topics while 20% will be spent on Tools and Methods and on Independent Investigations. Focused Science proposals must show relevance to the specific topic to which the proposal is submitted. Tools and Methods and Independent Investigations must include a one-half to one page description showing relevance to LWS goals and objectives and must fully justify the need for a fourth year if proposed; the tool(s) or science result(s) must be shown to satisfy LWS goals and objectives over some time scale (not necessarily within four years).

1.2.1. Focused Science Topics

A set of Focused Science Topics as further identified below have been chosen for emphasis in this solicitation (for further detail, also see the latest TR&T Steering Committee Report at http://lws-trt.gsfc.nasa.gov/trt_resources.htm). While the primary evaluation criteria remain unchanged (see *ROSES Summary of Solicitation*, Section V(a), and the *NASA Guidebook for Proposers*, Appendix C.2), the criterion for relevance includes relevance to one of the 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 four-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 Scientists at NASA's Goddard Space Flight Center (GSFC) and LWS Program Scientists 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.

The *NASA Guidebook for Proposers* states that "NASA strongly encourages PIs to specify only the most critically important personnel to aid in the execution of their proposals." LWS further emphasizes that Focus Teams will be formed from individual proposals selected in a Focus Topic. Therefore, individual proposals do not need to tackle the whole problem, but can instead seek to solve a piece of the problem.

The Focused Science Topics appropriate as the objectives for proposals to this LWS TR&T solicitation are as follows (linked to the four goals above):

a) Measure the properties of the solar dynamo that affect solar irradiance and active region generation.

Target Description: This task challenges proposers to characterize the properties of the solar dynamo that determine the strength of the solar activity cycle and its terrestrial consequences (e.g,. through irradiance changes and geomagnetic effects). Recent advances in modeling promise to provide accurate forecasts of the strength and timing of solar cycles. Now Cycle 23, a longer than average and somewhat peculiar cycle, is ending, and the new Cycle 24, which has widely different predictions for its maximum activity level from different models, is beginning. In order to be useful for future cycle forecasting, models need to be constrained and related more closely to LWS impacts. Interpretation of available data from the SOlar and Heliospheric Observatory (SOHO), Global Oscillation Network Group (GONG), Synoptic Optical Long-term Investigations of the Sun (SOLIS), other space- and ground-based sources, and the upcoming Solar

Dynamics Observatory (SDO) mission toward this resolution is timely and may lead to new observational strategies as the solar activity level increases.

Goals and Measures of Success: Successful investigations should help us to discriminate between and improve dynamo models. This requires improved measurements of critical subsurface flows, including the expected deep meridional flow, detection of the subsurface magnetic fields, and a determination of the influences of the solar polar properties on the dynamo. The connections between dynamo operation and the properties of the active regions that give rise to terrestrial effects also require clarification. Solar irradiance variations are determined by both sunspot and plage areas. What in the dynamo action determines this combination? Similarly, significant eruptive events can occur during both large and small activity cycles. An understanding of what aspect of dynamo action gives rise to eruptive regions is needed.

Types of investigations:

- Development of methods to discriminate between subsurface magnetic fields and thermal structures;
- Determination of the properties of the deep meridional return flow;
- Analyses revealing how the magnetic and dynamic characteristics of the solar poles affect the dynamo and the solar activity cycle; and
- Use of observations to discriminate between models that forecast the properties of Cycle 24.

b) Use Inner Heliospheric Observations to better constrain Coronal Mass Ejection (CME) and Solar Energetic Particle (SEP) Event models.

Target Description: The inner heliosphere remains a frontier that has been minimally explored. Thus far, only the Helios mission and Pioneer Venus Orbiter (PVO) have probed this region in any depth. Yet it is key to understanding what happens to Interplanetary CMEs (ICMEs) and their SEP-accelerating shocks in transit from the Sun to the Earth. Now Messenger and Venus Express are providing some new observations. In conjunction with the Solar TErrestrial RElations Observatory (STEREO), the Wind satellite, the Advanced Composition Explorer (ACE), and SOHO, these make a changing constellation of space weather measurements useful for investigating both the widths and the radial evolution of heliospheric space weather phenomena. Planning is also underway for Solar Orbiter/Sentinels and a Solar Probe mission will finally explore this inner frontier in more detail. These upcoming mission opportunities are best exploited if available measurements are used together with our increased understanding to obtain new insights.

Goals and Measures of Success: The goal is to provide observational validation for inner heliosphere models, as well as updated information for new mission instrumentation and observational strategies. Measures of success for this Focused Science Topic include the ability to predict the evolution of shocks in the inner heliosphere that are inferred from remote sensing close to the Sun and in-situ measurements at Mercury’s orbit and beyond. This will require the characterization of coronal and solar wind properties into ~5-10 Rs where ICME shocks are inferred to form. Observational and theoretical tests that resolve contested issues such as the importance of scattering in energetic particle transport, the mode(s) of acceleration at the shock, and the nature and origin of the heavy ion contributions to energetic particle populations are desirable consequences. Improved diagnostics of the physics of CME ejecta evolution and their solar wind interaction as they travel into the heliosphere, accelerating or decelerating and undergoing distortions as they travel, will aid future forecasting efforts and provide Sun-to-Earth event model constraints.

Types of investigations:

- Retrospective analyses with modern tools and models of solar wind properties, CME/ICMEs and their SEP events observed during the Helios mission;
- Multispacecraft analyses of events detected at Messenger and Venus Express that use Sun-to-Earth event models; and
- Analyses of 0.3-1.0 AU suprathermal ions from a SEP event seed particle perspective.

c) Determine the possible role of galactic cosmic ray particles as a source for cloud condensation nuclei in the troposphere and lower stratosphere.

Target Description: It has been shown that the galactic cosmic rays (GCRs) reaching Earth, as measured by their by-product neutrons that reach ground level, vary by about 20% over the course of the solar cycle, with an inverse correlation to sunspot activity. Other by-products of these GCRs include the creation of ions in the lower atmosphere, specifically in the troposphere and lower stratosphere. It has been postulated that these ions could act as condensation nuclei, which, through subsequent coalescent stages, could lead to additional cloud condensation nuclei and, therefore, a change in the solar cycle dependence of the overall cloud coverage of the planet. Even if a substantial amount of such additional cloud coverage is indeed formed from the by-products of GCR energy deposition, there is still uncertainty about whether the radiative forcing from these clouds would cause a net increase or decrease in global temperatures. If they are high, thin clouds, then the net forcing is positive, warming the Earth. However, if the clouds are low and thick, then the net forcing is negative, increasing the Earth's albedo and cooling the planet. This Focused Science Topic seeks to resolve the question of whether GCRs have a significant influence on total cloud cover, and, therefore, address the issue of GCR effects on climate change.

Goals and Measures of Success: The goal is an objective interdisciplinary examination of relevant data and analyses of physical and chemical processes through which galactic cosmic rays influence the total cloud coverage of the planet. The measure of success is the degree to which the investigations definitively clarify the extent of their effects relative to those of solar radiative changes and other natural and anthropogenic influences.

Types of investigations:

- Experiments and/or calculations to determine the effects of particle-induced atmospheric chemistry and ionization changes on cloud cover and its associated thermal and dynamical effects;
- Robust examinations of the observations to quantify the relative influence of GCR precipitation on cloud cover; and
- Numerical experiments with atmospheric models to assess the direct and indirect effects of GCR-induced alterations to cloud cover.

d) Integrate Non-MHD/Kinetic Effects on Magnetic Reconnection, Particle Energization, and Plasma Heating into Global Models.

Target Description: Global magnetohydrodynamic (MHD) models of the magnetosphere are now routinely run to determine geospace conditions both retrospectively and in a forecast mode. However, such models lack the detailed physics needed to accurately describe the location, structure, and dynamics of the diffusion region where magnetic reconnection occurs, and thus the consequences. Recent advances in approaches beyond MHD (e.g, two-fluid (or Hall MHD), fully kinetic theory) have produced new insights on the role these processes play in controlling the dynamics and reconfigurations of magnetic fields, which in turn affect the radiation environment. However, there remains a gap between smaller-scale studies (involving, for example, reconnection, turbulence or collisionless shocks) and global modeling. This topic would bring together experts in two-fluid/kinetic processes, global modelers, and observers of the micro/macro scale interactions to determine how non-MHD/kinetic effects are affecting the global models and to develop schemes for including them.
Goals and Measures of Success: The goals of this Focused Science Topic are to determine how the treatment of non-MHD effects in MHD codes affects the results, including simulated storm and substorm events and the associated particle acceleration and magnetospheric reconfigurations and to develop schemes for incorporating such physics or parameterizations of the physics into global models. Reconnection and shock physics are of special importance for this Focused Science Topic. Measures of success include the ability to better simulate storm and substorm initiation and their effects. The availability of an approach to parameterizing effects of reconnection in heliophysics MHD models in general would be an especially desirable outcome.

Types of investigations:

- Development of magnetosphere models with the capability of accommodating subgrid scale physical phenomena;
- Development of kinetic and MHD or Hall MHD simulations that can be used to test parameterizations of the kinetic processes involved in reconnection;
- Application of such models to real or idealized magnetospheric disturbances to assess the importance of non-ideal-MHD physics in governing the dynamics of geospace;
- Observational studies that identify sites where reconnection, particle energization, and plasma heating occur and characterize their consequences (local as well as global); and

- Observational studies that span multiple spatial scales providing information on how non-MHD processes affect global scales.

e) Determine and quantify the responses of atmospheric/ionospheric composition and temperature to solar XUV spectral variability and energetic particles.

Target Description: With the recent availability of comprehensive solar spectral measurements at X-ray and ultraviolet (XUV) wavelengths, together with upper atmospheric chemistry and transport models, quantification of the full range of solar effects on chemically active minor constituents and ion composition in the ionosphere-thermosphere-mesosphere (I-T-M) system is now possible. Additional solar-driven variation is caused by the energetic particle environment, ranging from auroral fluxes to galactic cosmic rays. These sources have important influences on the chemistry, energetics, and dynamics of the lower thermosphere and ionosphere (e.g., on nitric oxide and ozone) via direct energy deposition and modulation of ion-neutral frictional heating. Observations of neutral composition and temperature for different phases of the solar cycle and for sporadic events are available through NASA missions like the Upper Atmosphere Research Satellite (UARS) and the Thermosphere Ionosphere Mesosphere Energetics and Dynamics mission (TIMED), as well as from other space- and ground-based instruments. Observations of ionospheric electron density are available through a variety of sources. In view of these advances, models of atmospheric/ionospheric composition and energetics that fully exploit the available estimates of external energetic inputs can now be developed to more accurately quantify solar effects in the middle and upper atmosphere.

Goals and Measures of Success: The goal of this topic is to determine how well our understanding of atmospheric/ionospheric processes, as incorporated in state-of-the-art models, is able to explain observed compositional and temperature effects in the middle and upper atmosphere caused by external energetic inputs, in order to be able to predict these effects under both normal and extreme conditions. The measure of success will be the ability to obtain closure between observations and models of short-term, solar-cycle, and long-term variability as functions of altitude.

Types of investigations:

- Development of global and regional process models and the application of such models to assess the response of the I-T-M system to variable energy inputs;
- Data analyses that provide new descriptions of external energy drivers;
- Observational studies that characterize atmospheric/ionospheric composition and temperature responses to energetic inputs; and
- Development of models that use data assimilation to reproduce past conditions as a test, and then use them to forecast future conditions and to make a case for certain ongoing observations.

1.2.2 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 (1) the development of new empirical methods or analysis techniques, such as local helioseismology, that can be used to forecast solar, interplanetary, and geospace activity; (2) the development of new feature recognition or artificial intelligence (AI) algorithms that can advance predictive capabilities for the LWS system; and (3) the development of software tools that can identify, retrieve, assimilate, and/or portray data in order to model results from different sources for LWS research and forecasting objectives. Tools that address the four LWS TR&T strategic goals will be especially welcome.

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

1.2.3 Independent Investigations

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

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 program 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 Section 3 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:

- The workshop must address a science or technology topic that is both timely and important to the goals of LWS.
- Workshops must focus on comparing and validating tools that have already been developed. Examples of possible workshops include 1) predicting all clear forecasting, 2) comparison of helioseismic techniques, and 3) velocity estimation methods.
- Other workshop topics must be cross-disciplinary in nature and bring together researchers from different disciplines in LWS science.
- 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.
- Workshops that encourage the training of new researchers in LWS system science are strongly encouraged.
- 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 or two such proposals may be selected for summer school activities not to exceed more than two years during the nominal four-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 Focused Science Topics described in Section 1.2.3.

3. Summary of Key Information

Expected annual program budget for new awards	~ $4 M
Number of new awards pending adequate proposals of merit	~ 30
Maximum duration of awards	4 years
Due date for Notice of Intent to propose (NOI)	September 19, 2008
Due date for proposals	October 17, 2008
Page limit for the central Science-Technical-Management section of proposal	15 pp except as noted in section 1.3; see also Chapter 2 of the *2008 NASA Guidebook for Proposers*
NASA strategic objective(s) which proposals must state and demonstrate relevance to	Every proposal must address one or more strategic goal or research objectives from Table 1 in the *ROSES Summary of Solicitation*. See also Sections I(a) and IV(e) of the *ROSES Summary of Solicitation*.
General information and overview of this solicitation	See the *ROSES Summary of Solicitation*.
Detailed instructions for the preparation and submission of proposals	See the *2008 NASA Guidebook for Proposers* at http://www.hq.nasa.gov/office/procurement/nraguidebook/.
Submission medium	Electronic proposal submission is required; no hard copy is required or permitted. See also Section IV of the *ROSES Summary of Solicitation* and Chapter 3 of the *2008 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	NNH08ZDA001N-LWSTRT
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