B.6 LIVING WITH A STAR: STRATEGIC CAPABILITY

NOTICE: Amended June 23, 2021. This Amendment releases the final text for this program element, which had been listed as "TBD". Proposal submission will not use the two-step process; neither Notices of Intent nor Step-1 proposals are requested for this program element. Proposals are due October 13, 2021. No Data Management Plans are requested for proposals to this opportunity. Instead, all models and software modules produced by participation in this program must be submitted to the Community Coordinated Modeling Center by the end of the period of performance, see Section 1.2.

1. Scope of Program

The Living With a Star Strategic Capability (LWSSC) program solicits proposals for the development of models for the coupled Sun-Earth and Sun-Solar System. Such models can act as tools for science investigations, as prototypes and test beds for prediction and specification capabilities, as frameworks for linking disparate data sets at vantage points throughout the Sun-Solar System, and as strategic planning aids for enabling exploration of outer space and testing new mission concepts.

LWS Strategic Capability (LWSSC) is a component of the Heliophysics Research Program and proposers interested in this program element should read B.1, the Heliophysics Research Program Overview for Heliophysics-specific requirements. Defaults for all ROSES elements are found in the ROSES *Summary of Solicitation and the Proposer's Guidebook* and the order of precedence is the following: This document (B.6) followed by B.1, followed by the ROSES *Summary of Solicitation*, and the *Proposer's Guidebook*. Proposers should review all of these resources to ensure compliance with Program requirements.

1.1 Solicited Investigations

This year the LWS program is soliciting two Strategic Capabilities topics:

- A global model of the magnetosphere (Section 2)
- A model of coronal mass ejection (CME) evolution and impact on the inner heliosphere (Section 3).

These areas are chosen for the maturity of their respective fields and the desire to produce tools for community use. These Strategic Capabilities, described in detail below, have been derived from information discussed in the LWS Program Analysis Group (LPAG) 2018, 2019 and 2020 Reports (reports are available at http://lwstrt.gsfc.nasa.gov/lpag).

The LWS Targeted Research and Technology (TR&T) Science Definition Team (SDT) (https://lwstrt.gsfc.nasa.gov/images/pdf/TRT_SDT_Report.pdf) identified the development of predictive and specification models for the coupled Sun-Earth system as critical for the TR&T program. These models are solicited as a distinct program element within the TR&T program.

Several changes have been implemented in this Strategic Capabilities opportunity. The period of performance has been reduced from five years to four years, and the number

of topics and anticipated number of selections has been reduced. The maximum annual budget, however, will remain $1M. These changes will allow an increase in the cadence of this program from every five years to every two years, depending on the availability of adequate funds. This will provide more frequent opportunities to propose to the LWSSC program.

1.2 CCMC Integration

Each proposing team will assign one team member as a liaison between the proposing team and Community Coordinated Modeling Center (CCMC) staff from the start of the project. This requirement is to ensure that the development effort will include ongoing input from CCMC staff from the start of the project so that the validation and implementation will be completed during the final year of the proposed effort. It is anticipated that the liaison will be a team member other than the PI.

Contact with the CCMC in advance of proposal submission is required to confirm the feasibility of the plans to implement the proposed model in accordance with CCMC requirements (contact maria.m.kuznetsova@nasa.gov for POC and further information). Documentation of an email exchange with the CCMC describing the feasibility of the proposed implementation plan is required and must be included as a "letter of support" following the references and citations for the Scientific/Technical/Management section of the proposal.

All models and software modules produced by participation in this program must be successfully installed and tested at CCMC systems by the end of the period of performance. Utilization of CCMC collaborative environments at NASA High-End Computing (HEC) facilities at Ames Research Center (ARC) and NASA approved clouds provided by CCMC for testing throughout the period of performance is encouraged.

Although this call does not require data management or archiving plans, the present LWSSC call does require certain material be submitted to the CCMC along with the developed codes and other documentation before the end of the period of performance. This includes data required as input to the developed model, data used during model validation, as well as model simulation outputs that result as part of the validation activities. For the case of required inputs from a large publicly available data set the location of this data set must be identified and access verified by CCMC staff as part of the comprehensive review described in Section 4.4.

Proposals must address the following items in a separate section titled "Addressing CCMC Requirements" that is included in the page limited Scientific/Technical/Management Section of the proposal:

- Specify the requirements for code development and delivery to CCMC, including how the proposed deliverables will be utilized at the CCMC.
- Describe approach(es) to achieve code portability, compatibility and I/O standardization in coordination with CCMC staff.
- Estimate computational/storage resources and other requirements for code implementation at CCMC. This is in addition to the standard HEC request and may require input from the CCMC.

- If the development of a user interface is required beyond CCMC web-based software systems, the proposal must describe how this will be accomplished. If investigators plan on developing their own interfaces, this should be done with coordination with CCMC staff throughout the period of performance to make sure that CCMC technical and security requirements are satisfied.
- Plan for a kick-off meeting with the CCMC to develop implementation plans that will guide the code development and implementation from the project inception.
- Testing plan for portability and compatibility for all models and codes including necessary reading, interpolation, post-processing, and visualization software. If applicable, model output readers and interpolators developed under the proposal will be included in the NASA open source CCMC Kamodo access and interpolation software (https://github.com/nasa/Kamodo).
- Plans for complete documentation of the developed code; step-by-step instructions on model installation, compilation, execution; a complete list of options and ranges for input parameters and other simulation settings; step-by-step instructions on post-processing of model output; a complete list of software and language dependencies, including version numbers; a complete set of model output metadata, including, but not limited to, the model name and version number and all possible output variables, their units, and their dimensional dependencies; as well as a comprehensive and validated user's manual. User manual validation will be done by the project liaison working jointly with CCMC staff during the onboarding process.
- Plans for a model validation program to be conducted during the final phase of the program in coordination with CCMC staff.
- Plans for or agreement to follow the CCMC model on-boarding procedure, which is a living document that can be updated based on lessons learned. The most up-to-date expectations among various stages of the CCMC model on-boarding process are at: https://ccmc.gsfc.nasa.gov/models/model_on_board.php.

1.3 Licensing

The Federal Government must be granted a license for full and unrestricted use of the software and any source code, transition to the CCMC, and possible transfer to space weather operations centers. This includes unrestricted public use. All source codes must be delivered to CCMC. CCMC does not distribute source code to or allow access by any entity without explicit permission from the code owner as defined in the CCMC's Rules of the Road Document, which may be found at: https://ccmc.gsfc.nasa.gov/submissions/CCMC_Rules.doc. Model output post-processing tools (e.g., readers and interpolators) to be included in the NASA open source CCMC Kamodo access and interpolation software (https://github.com/nasa/Kamodo) will also be open sourced.

1.4 Science Traceability

Proposals to LWSSC shall link the proposed work to the NASA Heliophysics Science Objectives (see B.1). The ability to determine whether a proposed investigation is successful depends on a well-formulated articulation of the proposed science question(s) and modeling objectives. The proposal must clearly define a set of science

questions that are relevant to the LWS program and the Strategic Capabilities described in Section 2 or 3. These are a set of questions that can be addressed by the proposed model once it is completed. The connection of these science questions to the modeling capabilities, requirements, and projected performance must be clearly documented in the text of the proposal. The adequacy of the connection between modeling capability and science questions will be an important component of the panel evaluation. Since the purpose of this call is the development of modeling capabilities, proposers are expected to identify but not answer science questions as part of the proposed effort.

1.5 High End Computing

Awardees may request time on the NASA High Performance Computing (HEC) facilities at Ames Research Center (ARC). Information on applying for computer time on NASA's HEC facilities can be found in the *ROSES Summary of Solicitation*, Section I(d). Note: When onboarding a model at CCMC, awardees may be asked to utilize a NASA approved cloud environment provided by the CCMC. Selected investigations will be considered for the allocation of the requested computing resources, although the fully requested level cannot be guaranteed.

2. Strategic Capability #1: A global model of the magnetosphere.

Capability Description: Develop the next generation of reliable, stable and accurate global model, or coupled set of models of the magnetosphere that extend significantly beyond single-fluid MHD, capable of including electron physics, and a multi-component ion description.

LWS Strategic Need: The development of a model, or coupled set of models, that allows a more realistic assessment of small-scale processes on the global magnetosphere system (and vice versa) that will address needs for both basic and applied research. The development of this capability is timely, as many research approaches exist with partial implementation of the desired capabilities/features that go beyond single-fluid MHD description (hybrid codes, embedded PIC, multispecies/multi-ion MHD, spectral transform methods, moment expansion methods, etc.); many of these developments have been outcomes of past efforts sponsored by the Heliophysics Division Programs such as LWS Science, Theory, Modeling, Simulations (TMS), and Heliophysics Supporting Research (HSR). However, many of these efforts are still considered to be in the early stages of development, with stable and accurate implementations still elusive. At the CCMC, global magnetospheric models are mostly single fluid at this stage.

Part of this model development effort is the utilization of data, either as input or for validation. Numerous data sources currently exist that would meet these requirements (Van Allen Probes, MMS, Themis, etc.). Any data set to be used by the proposed effort must be in a publicly available archive 30 days before the proposal deadline (see B.1 for further information). The use of subsequently available data sets is allowed if a proposal is selected but the proposal will be evaluated based on currently available data only.

Target Objectives: The following Target Objectives reflect a full range of capabilities addressed by the Capability Description above:

- Improved modeling of reconnection and electron scale physics in general;
- Modeling turbulent processes in foreshock and magnetosheath;
- The ability to model non-MHD waves in a global context;
- Inclusion of Hall MHD physics;
- Inclusion of multi-species plasma ion populations of both solar wind and ionospheric origin;
- Improved representation of plasmasphere dynamics and ionospheric outflows;
- New approaches to solving the Vlasov-Maxwell equations such as moment expansion or spectral transform methods;
- Improvements to computational stability and efficiency, novel approaches to reduce computation demand without impacting the physics;
- Extensive validation of codes – metrics on code diffusivity, energy & momentum conservation, accuracy in solving equations, deviation from pure MHD, etc.

Other Target Objectives germane to this Strategic Capability, defined in this Capability Description and LWS Strategic Need, may be included but their relevance and importance will be evaluated by the review panel.

Successful proposals will incorporate several objectives and defend these choices based on the scientific importance of the objective, feasibility of the method to be used for implementation, and other factors deemed relevant by the proposer. While proposals should address multiple objectives, covering all these objectives in a single proposal is not required.

3. Strategic Capability #2: A model of CME evolution and impact on the inner heliosphere

Capability Description: Derive a model of, or coupled set of models of, CME precursor evolution, CME eruption and propagation, associated magnetic field properties, and Solar Energetic Particle (SEP) acceleration and transport within the context of realistic models from the solar surface, through the corona, and the inner heliosphere.

LWS Strategic Need: The development of a model, or coupled set of models, of CMEs and associated SEPs from the sun through the inner heliosphere that will address needs for both basic and applied research. The development of this capability is timely, in part because of the numerous efforts that currently exist within the Heliophysics community as well as the growing need for the fundamental understanding required by applied research. Previous efforts sponsored by the Heliophysics Division (LWS Strategic Capabilities, LWS Focused Science Topics, Theory, Modeling, Simulation (TMS), etc.) have funded the development of models or algorithms that are clearly relevant components and represent the pieces that can address this larger problem. While numerous data sources currently exist that would meet the requirements of applied research, there may be limitations in available data that could constrain the improvements realized by the suite of models developed under this program. Nonetheless, progress is expected in the development of a modeling infra-structure and, when sufficiently mature, can be used to better interpret data through contextual analysis, and overcome some of the weaknesses in the data. These weaknesses in the data and their impacts should be addressed in the proposal.

Part of this model development effort is the utilization of data, either as input or for validation. Numerous publicly available data sources currently exist that would meet these requirements (e.g., SOHO, Stereo, SDO, IRIS, as well as various ground-based data sets). Any data set to be used by the proposed effort must be in a publicly available archive 30 days before the proposal deadline (see B.1 for further information). The use of subsequently available data sets is allowed if a proposal is selected but the proposal will be evaluated based on currently available data only.

Target Objectives: The following Target Objectives reflect a full range of capabilities addressed by the Capability Description above:

- Combine data assimilation and model simulation to successfully span multiple spatial scales and improves the understanding of CME evolution in the corona and inner heliosphere.
- Incorporate new capabilities to examine the evolution of CMEs and their substructures as they transit the corona and inner heliosphere and interact with the background wind.
- Integrate or model new observations or combination of observations to extract additional physical information about the evolution of CMEs in the corona and inner heliosphere.
- Incorporate new techniques or simulation capabilities that leads to improved forecasts of the space weather impact on the Earth system as a result of improved understanding of CMEs and their evolution through the corona and inner heliosphere.
- Include theoretical models for explaining the observations of anomalous composition of ^{3}He, heavy ions and ultra-heavy nuclei.
- A comprehensive combination of models and observations for detailed understanding of propagation of flare particles from the Sun to 1 AU.
- Incorporation of the most current understanding of how flare particles propagate out of the acceleration region and contribute to large SEP events, either as ‘seed’ particles or a component of the SEP population
- Incorporation of the most current understanding of how magnetic energy is converted and distributed into electrons and ions and how the energy is partitioned into heating and nonthermal acceleration.

Other Target Objectives germane to this Strategic Capability, defined in this Capability Description and LWS Strategic Need, may be included but their relevance and importance will be evaluated by the review panel.

Successful proposals will incorporate several objectives and defend these choices based on the scientific importance of the objective, feasibility of the method to be used for implementation, and other factors deemed relevant by the proposer. While proposals should address multiple objectives, covering all these objectives in a single proposal is not required.

4. Submission and Evaluation Guidelines

4.1 General Guidelines

Proposal submission will not use the two-step process. Neither Notices of Intent (NOIs) nor Step-1 proposals are requested for this program element. The guidelines for the technical contents of the proposal are provided in Section 4.2, below.

A proposal must be submitted electronically by the due date given in Tables 2 and 3 of ROSES by an Authorized Organizational Representative (AOR) from the institution of the PI. A budget and other specified information is required.

An individual may be Principal Investigator of one and only one LWSSC proposal. The Principal Investigator is expected to invest a substantial portion of his/her time. A minimum of 2 months/year is required as the PI time commitment but the review panel will evaluate the adequacy of the proposed PI time commitment when evaluating the proposed resources compared to the schedule and work plan (see Section 4.2, below). Co-Investigators must each have a specific and defined task in the project, and the task must be essential to completion of the project. Collaborators are required to have clearly defined tasks in the project. Letters of Certification for any foreign Collaborators must be included following the current and pending.

Proposals may be declared non-compliant if they are outside the scope of the LWSSC Program as defined in Sections 1-3, or if they fail to meet submission guidelines specified below.

Proposers are strongly encouraged to provide names and contact information of five experts qualified to review their proposal. These experts must not be from the institutions of the PI or Co-Is. The PI can confidentially provide this information by sending an email to the Point of Contact listed in Section 7 of this program element by the due date of the proposal.

4.2 Proposal Content

Guidelines for content and formatting proposals are specified in Section IV(b)ii of the *ROSES Summary of Solicitation*. Proposals must adhere to formatting requirements (e.g., margins, font sizes, line spacing).

The Scientific/Technical/Management section of Proposals are restricted to twenty (20) pages and, in addition to a separate section titled "Addressing CCMC Requirements" described in Section 1.2 above, proposals must include the following information:

- A detailed description of the science questions, why they are compelling, how these questions relate to the Strategic Goal described in Section 2 or 3, including how the proposed work will address the goals and objectives described in Sections 2 or 3. This traceability is outlined in Section 1.4 Science Traceability.
- A description of existing algorithms, which are the basis of existing models, previous uses or applications, anticipated modifications of these algorithms, and methods to implement, test, and validate the current and/or modified algorithms.
- A description of new or significantly modified algorithms and the scientific basis for the proposed formulation, how this will be implemented, tested, and validated.

- A description of the plans to document the following: the complete overview of algorithm development and modification, the final validated, fully commented, and documented source code to be provided to the CCMC, the results of validation activities, and the interaction and collaboration with CCMC Staff. All such documented items must be part of a comprehensive final report generated at the completion of the project.
- A description of how the resulting model(s) or software module(s) will be validated, documented, and delivered to the CCMC during the final year of the period of performance. The validation procedure outlined in the proposal must include uncertainty analysis using any appropriate methods determined by the proposer.
- A set of clearly defined milestones and a description of how and when these milestones will be accomplished.
- A detailed schedule and work plan covering all aspects of the code development, validation, delivery, etc.; including a plan for the completions of the above milestones.
- A description of the anticipated development of any required user interface. This includes any model that requires the use of NASA HEC to operate. PIs will work with the CCMC to develop a user interface that will be hosted by the CCMC and will allow users to access and run the developed codes through the CCMC.
- A description of steps planned to ensure compliance with requirements presented in Section 1.3 Licensing.

Please note that the estimate of the required computing resources should consider the aggregated computing time per year (number of runs times, number of processors per run times, number of hours per run), as well as the associated storage capacity neededto support the code development, validation, and implementation at the CCMC.

4.3 Evaluation Criteria

Evaluation criteria for this solicitation are given in the *NASA Guidebook for Proposers* (see below for reference). These criteria are intrinsic merit, relevance to this program element (e.g., to the Strategic Capabilities listed in Sections 2 or 3), and cost reasonableness. In addition to the factors given in the *NASA Guidebook for Proposers*, the evaluation criterion intrinsic merit also includes the following factors:

- How the proposal addresses the requirements, goals, and objectives presented in Sections 2 or 3; The appropriateness of the proposed model to address the proposed science questions, the feasibility of accomplishing the proposed model development and, how the proposed modeling capability will benefit and be used by the community;
- How the proposal addresses the requirements presented in Section 1.2 on CCMC Integration;
- How the proposal incorporates the required proposal content presented in Section 4.2;
- Compliance with requirements to provide public access to any tools and value-added products developed and provided to the CCMC;

Cost reasonableness will be evaluated by the review panel by comparing the proposed effort to the proposed resources (time commitments for algorithm and code development as well as validation, computational resources required, etc.).

Given the unique nature of the LWS's Strategic Capability program, proposal reviewers will include both scientific peers and knowledgeable representatives from the Heliophysics computational community.

In addition, the treatment of uncertainty will be evaluated by the review panel which will assign a strength or weakness based on the treatment presented in the proposal. Uncertainty may be coupled to the proposed validation process. Proposals that fail to address uncertainty will be assigned a Major Weakness in the evaluation and may be considered unselectable.

4.4 After Selection

The program will publicly post links to the abstracts of all selected proposals and their annual progress reports, and/or refined data products, at https://lwstrt.gsfc.nasa.gov/ and the CCMC. It will be the responsibility of the PI to ensure that all reports contain no sensitive or proprietary information since they will be made available to the CCMC and the public without restriction.

In addition to the regularly scheduled annual progress reports due for proposals selected in response to this opportunity, there will be a comprehensive review of the milestones accomplished at the end of the third year after award initiation and prior to the release of year-4 funding. Each selected principal investigator will submit a detailed status review to the LWS Program Scientist describing (1) progress to date, (2) problems encountered, and (3) plans for the final year of funding. At the discretion of the LWS Program Scientist, each principal investigator will present this review, either in person or virtually, to a panel of experts including representatives of the CCMC. Based on this review, an assessment of the progress will be made to determine if the model development is ready to move to the final stage and complete the transfer of developed models to the CCMC. Additional details of this assessment process will be provided to selected proposers during the first year of the award. Consistent with the policy of routinely seeking input from the scientific community, NASA will invite appropriate members of the research and user community to evaluate the progress of selected proposals at this comprehensive review. With the findings from these reviews, NASA will then provide the opportunity to the PI teams to revise their plans when requesting continued funding for the final year.

5. Award Types

The Heliophysics LWS Science program awards funds through three vehicles: (1) grants, (2) interagency transfers, and (3) awards to NASA centers. This call will not award contracts, as it would not be appropriate for the nature of the work solicited. Please also see Section II(a) of the *ROSES-2021 Summary of Solicitation.*

6. Available Funds

The total funding available in Fiscal Year (FY) 2021 for new proposals submitted in response to this solicitation is expected to be about $4M. This funding is expected to

support up to two (2) proposals from each Strategic Goal, for a total of up to four (4) awards. Proposals for efforts up to a maximum of four years are anticipated. This will include three years of algorithm and code development in coordination with the CCMC staff, with a fourth year to finalize the validation and implementation of the developed code at the CCMC.

The total budget for any award may not exceed $1M per year for a period of performance of up to four years.

7. Summary of Key Information

Expected program budget for first year of new awards	~$4M
Number of new awards pending adequate proposals of merit	4
Maximum duration of awards	4 years
Due date for proposals	See Tables 2 and 3 of this ROSES NRA.
Planning date for start of investigation	Within 6 months after proposal receipt.
Page limit for the central Science-Technical-Management section of full proposal	20 pages. See also Table 1 of *the ROSES-2021 Summary of Solicitation* and the *NASA Guidebook for Proposers*
Relevance	This program is relevant to the Heliophysics questions and goals in the NASA Science Plan. Proposals that are relevant to this program are, by definition, relevant to NASA.
General information and overview of this solicitation	See the *ROSES-2021 Summary of Solicitation*.
General requirements for content of proposals	See B.1, The Heliophysics Research Program Overview, and Section IV and Table 1 of *the ROSES Summary of Solicitation*.
Detailed instructions for the submission of proposals	Please see NSPIRES Online Help, the *2021 NASA Guidebook for Proposers* and Section IV(b) of *the ROSES Summary of Solicitation*.
Submission medium	Electronic proposal submission is required; no hard copy is permitted.
Web site for submission proposal via NSPIRES	http://nspires.nasaprs.com/ (help desk available at nspires-help@nasaprs.com or (202) 479-9376)
Web site for submission 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	NNH21ZDA001N-LWSSC

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