NASA SBIR 2022 Phase I Solicitation

S14.01 Space Weather Research-to-Operations/Operations-to-Research (R2O/O2R) Technology Development

Lead Center: MSFC

Participating Center(s): ARC, GSFC, JPL, JSC, LaRC

Scope Title

Space Weather Research-to-Operations/Operations-to-Research (R2O/O2R) Technology Development and Commercial Applications

Scope Description

Space weather has the potential to disrupt telecommunications; aircraft and satellite systems; electric power subsystems; and position, navigation, and timing services. Given the importance of these systems to our national well-being, NASA's Heliophysics Division invests in activities to improve the understanding of these phenomena and to enable new monitoring, prediction, and mitigation strategies.

The national direction for this work is organized by the Space Weather Operations, Research, and Mitigation (SWORM) Working Group, which is a Federal interagency coordinating body organized under the Space Weather, Security, and Hazards (SWSH) Subcommittee. The SWSH is a part of the National Science and Technology Council (NSTC) Committee on Homeland and National Security, organized under the Office of Science and Technology Policy (OSTP). The SWORM coordinates Federal Government departments and agencies to meet the goals and objectives specified in the National Space Weather Strategy and Action Plan (NSWSAP) and in the Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act.

NASA's role under the NSWSAP and PROSWIFT Act is to provide increased understanding of the fundamental physics of the Sun-Earth system through space-based observations and modeling, the development of new space-based space-weather technologies and missions, and through monitoring of space weather for NASA's space missions. This includes research that advances operational and commercial space-weather science and technology.

This subtopic solicits new, enabling space-weather technologies as part of NASA's response to these national objectives. While this subtopic will consider all concepts demonstrably related to NASA's R2O/O2R responsibilities outlined in the NSWSAP, four areas have been identified for priority development (not in priority order):

(1) Space-weather forecasting technologies, techniques, and applications: Innovative technologies and techniques are solicited that explore and enable the transition of tools, models, data, and knowledge from research to operational environments. This includes the preparation and validation of existing science models that may be suitable for transition to operational use. Coordination with existing NASA capabilities, such as the Space Radiation Analysis Group (SRAG) at Johnson Space Center (JSC), the Community Coordinated Modeling Center (CCMC) at

Goddard Space Flight Center (GSFC), and the Short-term Prediction Research and Transition (SPoRT) Center at Marshall Space Flight Center (MSFC), is appropriate and encouraged. Areas of special interest include, but are not limited to:

- Lunar space environment characterization tools that can be employed by NASA to enhance protection of crewed and uncrewed missions to cis-lunar and lunar surface missions.
- Specifications and/or forecasts of the energetic particle and plasma conditions encountered by spacecraft within Earth’s magnetosphere, as well as products that directly aid spacecraft anomaly resolution and benefit end users such as spacecraft operators.
- Approaches that potentially lead to 2- to 3-day forecasts of atmospheric drag effects on satellites and improvement in the quantification of orbital uncertainties in low-Earth-orbit (LEO) altitude ranges (up to ~2,000 km).
- Techniques that enable the characterization and prediction of ionospheric variability that induces scintillations, which impact communication and global navigation and positioning systems.
- Longer range (2 to 3 days) forecasting of solar particle events (SPEs) and an improved all-clear, SPE-forecasting capability.

(2) Commercial and decision-making applications for space-weather technologies: Innovative techniques and solutions are solicited that extend to commercial entities the use of new technology and knowledge about space weather. The NSWSAP and the PROSWIFT Act specifically call out the need to test, evaluate, and deploy technologies and devices to mitigate the effects of space weather on communication systems, geomagnetic disturbances on the electrical power grid, or radiation events on satellites. In addition, the policy and legislation include the development of processes to improve the transition of research approaches to operations, to support operational partners, and to serve society. Proposals of interest could include, but are not limited to:

- Descriptions and development of standards and best practices to improve the resilience of equipment to space-weather events.
- Efforts to bridge the gap between heliophysics science and society; these proposals would apply NASA data to the decision-making process of an end user to improve life on Earth. This work will power innovative projects through the use in novel ways of NASA space-weather data and will support decision making by a diverse community of users that NASA may not frequently engage. Integrating NASA data into the decision-making process of a particular user or user community is important for this solicitation.
- A description of a decision that will be the focus of a project, how the organization currently makes that decision, and how NASA data will be integrated into and will benefit that process.

Of specific interest are non-operational applications (i.e., not NOAA or DoD) with nontraditional users (e.g., a user who has not used NASA data before). Success could be an organization using NASA space-weather data to inform a decision they make, so that the use of these data tangibly benefits the performance of the organization. Both commercial applications and noncommercial applications are of high interest and are encouraged.

(3) Space weather advanced data-driven discovery techniques: A particular challenge is to combine the sparse, vastly distributed data sources available with realistic models of the near-Earth space environment. Data assimilation and other cutting-edge, data-driven discovery innovations are solicited that enable tools and protocols for the operational space-weather community. Priority will be given to proposals that:

- Develop data assimilation space-weather applications or technologies desired by established space-weather operational organizations.
- Integrate data from assets that typically do not share similar time series, utilize different measurement techniques (e.g., imaging vs. in situ particles and fields), or are distributed throughout the heliosphere.
- Provide new data-driven operational forecasting tools that can be straightforwardly validated by the CCMC or another equally robust validation methodology.
- Integrate underutilized, unexplored, or nontraditional resources.

Many existing or planned commercial constellations may include useful space-weather-exploitable data (e.g., iridium system magnetometer data or space-based radio occultation for ionospheric specification). Other possible data sources are global-navigation-satellite-system- (GNSS-) equipped constellations (for total electron content

(TEC) and/or drag information) and imaging constellations (tapping into unused nighttime observations of aurorae).

(4) Space Weather Instrumentation: Heliophysics science relies on a wide variety of instrumentation for its research and often makes its data available in near real time for space-weather forecasting purposes. Ideas are solicited for instrument concepts, flight architectures, and reporting systems that enable enhanced, more informative, robust, and effective measurements for space-weather monitoring and forecasting systems. Opportunities for improving measurements include increased spatial and temporal resolution, fidelity, promptness, and measurement-system reliability. This includes the miniaturization of existing systems and/or technologies deployable as an array of CubeSats. To be considered for investment, SBIR technologies should demonstrate comparable, or better, precision and accuracy when compared to the current state of the art. Further, SBIR instrument designs should avoid duplicating current NASA research spacecraft arrays or detector systems, including those currently in formulation or development, such as, but not limited to Interstellar Mapping and Acceleration Probe (IMAP), Geospace Dynamics Constellation (GDC), Dynamical Neutral Atmosphere-Ionosphere Coupling (DYNAMIC), Magnetosphere Energetics, Dynamics, and Ionospheric Coupling Investigation (MEDICI), Explorer concepts, Advanced Composite Solar Sail System (ACS3), Heliophysics Environmental and Radiation Measurement Experiment Suite (HERMES), Solar Cruiser, and Global Lyman-alpha Imagers of the Dynamic Exosphere (GLIDE).

Proposals must demonstrate an understanding of the current state of the art, describe how the proposed innovation is superior, and provide a feasible plan to develop the technology and infuse into a specific activity listed within the NSWSAP and the PROSWIFT Act.

Expected TRL or TRL Range at completion of the Project

3 to 8

Primary Technology Taxonomy

Level 1

TX 11 Software, Modeling, Simulation, and Information Processing

Level 2

TX 11.X Other Software, Modeling, Simulation, and Information Processing

Desired Deliverables of Phase I and Phase II

- Prototype
- Hardware
- Software

Desired Deliverables Description

Space weather is a broad umbrella encompassing science, engineering, applications, and operations. The goal of this SBIR is to generate products or services (“deliverables”) that enable end-user action. The deliverables can be applied, for example, to space-weather hazard assessments, real-time situational awareness, or to plan protective mitigation actions. Deliverables can be in the form of new data, new techniques, new instrumentation, and/or predictive models that are prepared/validated for transition into operations:

- Phase I deliverables are proof-of-concept data and/or detailed technique, instrument, or model development plans that have sufficient fidelity to assess technical, management, cost, and schedule risk. Phase I deliverables should also delineate the scope and benefit of the proposed products that could be realized as a result of Phase II and what further scope and benefit necessarily requires further development after Phase II.
- Phase II deliverables are functioning prototype versions of the proposed technologies that have been tested in a realistic environment or within a standard space-weather-community development and validation

framework. The extent of the prototype development and testing will vary with the technology and will be evaluated as part of the Phase II proposal. Phase II deliverables should also include/delineate any further work that would be required to bring the technologies to full operational and commercial use.

State of the Art and Critical Gaps

- We do not yet know how to predict what phenomena need to be predicted.
- We do not yet know how quantitatively good/bad our operational capabilities (metrics) are.
- Mechanisms do not yet exist to enable a broad range of the community to participate in the improvement of operational models.
- The research environment advances understanding rather than the improvement of operational products.

Space weather poses a constant threat to the Nation’s critical infrastructure, our satellites in orbit, and our crewed and uncrewed space activities. Extreme space-weather events can cause substantial harm to our Nation’s security and economic vitality. Preparing for space-weather events is an important aspect of American resilience that bolsters national and homeland security, and facilitates continued U.S. leadership in space. A robust space-weather program and its associated forecasting capabilities are essential for NASA’s future exploration success.

Relevance / Science Traceability

This SBIR subtopic enables NASA to demonstrate progress against NASA Goal 1.4: Understand the Sun and its interactions with Earth and the solar system, including space weather.

These applied research projects directly address NASA's role within the SWORM Working Group, which is a Federal interagency coordinating body organized under the SWSH Subcommittee. The SWSH is a part of the NSTC Committee on Homeland and National Security, organized under the OSTP. The SWORM coordinates Federal Government departments and agencies to meet the goals and objectives specified in the NSWSAP and in the PROSWIFT Act.

The Heliophysics Space Weather Science Application (SWxSA) establishes an expanded role for NASA in space-weather science under a single element, consistent with the recommendation of the National Research Council (NRC) Decadal Survey and the OSTP/SWORM 2019-NSWSAP. SWxSA competes ideas and products, leverages existing agency capabilities, collaborates with other agencies, and fosters partnership with user communities. SWxSA is distinguishable from other Heliophysics research elements in that it is specifically focused on investigations that significantly advance understanding of space weather; this progress is applied to enable more accurate characterization and predictions with longer lead time. The Heliophysics Living With a Star (LWS) Program has established a path forward to meet NASA’s obligations to the research relevant to space weather and is a significant source of input to SWxSA. Further involvement by the emerging Heliophysics space-weather commercial community has the potential to significantly advance the space-weather application obligations portion of the mandate.

Astronauts in Earth orbit are not protected by the Earth's atmosphere and are exposed to space radiation such as galactic cosmic rays and solar-energetic particles. Further, when astronauts travel outside Earth’s magnetosphere, they are exposed to even more radiation. A robust space-weather program and associated forecasting capabilities is essential for NASA's future exploration success.

References

Public Law 116-181—Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow Act: The Promoting Research and Observations of Space Weather to Improve the Forecasting of Tomorrow (PROSWIFT) Act was signed into law October 21, 2020. This law establishes the policy of the United States to protect its citizens from the effects of space weather on in-space resources and ground-based infrastructure by supporting space-weather research to include forecasts and predictions. Using a strategy of interagency collaboration, within and outside the Federal Government to include international partners, the PROSWIFT Act seeks to ameliorate social and financial impacts of space-weather events to society.

Executive Order 13744 – Coordinating Efforts to Prepare the Nation for Space Weather Events describes the policy of the United States with respect to preparations for space-weather events so that economic loss and human

hardship will be minimized.

The SWORM Working Group is a Federal interagency coordinating body organized under the SWSH Subcommittee. The SWSH is a part of the NSTC Committee on Homeland and National Security, organized under the OSTP. The SWORM coordinates Federal Government departments and Agencies to meet the goals and objectives specified in the National Space Weather Strategy and Action Plan released in March 2019.

National Space Weather Strategy and Action Plan: The White House Executive OSTP released the NSWSAP on March 26th, 2019, during the National Space Council meeting in Huntsville, Alabama. This strategy and action plan is an update to the original NSWSAP, released in October 2015.

Space Weather Phase 1 Benchmarks is a document created by the SWORM subcommittee, and the benchmarks describe a space-weather event's ability to affect the United States. The purpose of the benchmarks is to provide input for creating engineering standards, to develop risk assessments and estimates, establish thresholds for action, develop mitigation procedures, and enhance planning for response and recovery.

An Executive Order (EO) on Coordinating National Resilience to Electromagnetic Pulses (EMPs) was released by the White House on March 26, 2019. The EO identifies the disruptive impacts an EMP has on technology and critical infrastructure systems, whether the EMP is human made or naturally occurring. The EO outlines how the Federal Government will prepare for and mitigate the effects of EMPs by an efficient and cost-effective approach.