Grand Challenges in Integrative Geospace Sciences: Advancing National Space Weather Expertise and Research toward Societal Resilience (ANSWERS)

PROGRAM SOLICITATION
NSF 21-577

National Science Foundation

Directorate for Geosciences
Division of Atmospheric and Geospace Sciences

Full Proposal Deadline(s) (due by 5 p.m. submitter's local time):

August 23, 2021

IMPORTANT INFORMATION AND REVISION NOTES

Important Information

Innovating and migrating proposal preparation and submission capabilities from FastLane to Research.gov is part of the ongoing NSF information technology modernization efforts, as described in Important Notice No. 147 . In support of these efforts, proposals submitted in response to this program solicitation must be prepared and submitted via Research.gov or via Grants.gov, and may not be prepared or submitted via FastLane.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 20-1), which is effective for proposals submitted, or due, on or after June 1, 2020.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Grand Challenges in Integrative Geospace Sciences: Advancing National Space Weather Expertise and Research toward Societal Resilience (ANSWERS)

Synopsis of Program:

The Advancing National Space Weather Expertise and Research toward Societal resilience (ANSWERS) solicitation has the goal to bring together collaborative teams of solar and geospace observers, theorists, modelers, experimenters, educators and computational experts to address some of the most challenging problems in solar and space physics and space weather. The purview of this new holistic solicitation goes beyond the scope of each of the long-standing programs in the Geospace Section (GS) of the NSF Division of Atmospheric and Geospace Science (AGS): Aeronomy (AER), Coupling, Energetics, and Dynamics of Atmospheric Regions (CEDAR), Geospace Environment Modeling (GEM), Magnetospheric Physics (MAG), Solar Terrestrial Research (STR), and Solar, Heliospheric, and INterplanetary Environment (SHINE). ANSWERS enables deep and transformative understanding of the dynamic, integrated Sun-Earth system and the solar and terrestrial drivers of space weather and their effects “from Sun to mud.” In combination with forward-looking educational endeavors, ANSWERS also aims to advance the nation’s science, technology, engineering, and mathematics (STEM) expertise and build societal resilience against space weather hazards.

Cognizant Program Officer(s):

Please note that the following information is current at the time of publishing. See program website for any updates to the points of contact.

- Mangala Sharma, Program Director, Space Weather Research, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov
- Zhuangren (Alan) Liu, Program Director, Aeronomy/CEDAR, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov
- Ilia I. Roussev, Program Director, Solar Terrestrial research/SHINE, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov
- Lisa M. Winter, Program Director, Magnetospheric Physics/GEM, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov

Applicable Catalog of Federal Domestic Assistance (CFDA) Number(s):

- 47.050 --- Geosciences

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 4 to 6

Anticipated Funding Amount: $7,500,000

Approximately 2-3 awards each up to $900,000 total over 3 years for SMALL team efforts.

Approximately 2-3 awards each up to $2,500,000 total over up to 4 years for LARGE team efforts.

The budget for a given proposal should be commensurate with the complexity of the proposed research and education efforts.

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.
- Non-profit, non-academic organizations: Independent museums, observatories, research labs, professional societies and similar organizations in the U.S. associated with educational or research activities.
- For-profit organizations: U.S. commercial organizations, especially small businesses with strong capabilities in scientific or engineering research or education.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

- Although there is no limit on the number of proposals per organization, an organization will only be allowed to receive one ANSWERS award as the lead organization. The organization may also participate in one additional award as a subawardee organization.

Limit on Number of Proposals per PI or Co-PI: 2

- An individual may serve as PI, co-PI, or other senior personnel on no more than two (2) ANSWERS proposals. In cases where an individual appears as senior personnel in more than two proposals, only the first two submitted proposals will be accepted; all other ANSWERS proposals involving that individual will be returned without review.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not required
- **Preliminary Proposal Submission:** Not required
- **Full Proposals:**
  - Full Proposals submitted via Research.gov: *NSF Proposal and Award Policies and Procedures Guide* (PAPPG) guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.
  - Full Proposals submitted via Grants.gov: *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov* guidelines apply (Note: The *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide).

B. Budgetary Information

- **Cost Sharing Requirements:**

  Inclusion of voluntary committed cost sharing is prohibited.

- **Indirect Cost (F&A) Limitations:**

  Not Applicable

- **Other Budgetary Limitations:**

  Other budgetary limitations apply. Please see the full text of this solicitation for further information.

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

  August 23, 2021

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria. Additional merit review criteria apply. Please see the full text of this solicitation for further information.

Award Administration Information

Award Conditions:

Standard NSF award conditions apply.

Reporting Requirements:

Standard NSF reporting requirements apply.

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I. INTRODUCTION

Cutting-edge observations, modeling, and theoretical investigations in solar physics and geospace sciences have revealed a wealth of information about the Sun's atmosphere and solar wind, and the geospace system encompassing Earth's radiation belts, magnetosphere, and ionosphere as well as the lower atmosphere. Solar activity and forcing from the Earth's geospace layers and lower atmosphere (including tidal and gravity waves) drive various space weather (SWx) phenomena such as auroras, traveling ionospheric disturbances, and geomagnetic storms. These space weather elements have the potential to create risks to human-built infrastructure and technology, and thus to our technologically-dependent society. Advancing solar and geospace sciences and the scientific understanding of SWx are critical to scientific discovery and vital for the nation's economy, security, resilience, and well-being.

Recent legislation, Presidential executive orders, and federal interagency working group reports have made clear the need for sustained and enhanced efforts to understand space weather "from Sun-to-mud." Consensus recommendations from the research community, including the 2013 National Academies report Solar and Space Physics: A Science for a Technological Society (Decadal Survey, hereafter) and the Investments in Critical Capabilities for Geospace Science 2016-2025: Portfolio Review of the Geospace Section of the Division of Atmospheric and Geospace Sciences (GS Portfolio Review, hereafter) have emphasized the need for large collaborative, integrative activities—such as support for grand challenge projects—that expand and go beyond the scope of each of the individual NSF CEDAR, GEM, and SHINE programs. Supporting integrative science investigations in geospace and SWx goes hand-in-hand with strengthening societal resilience to SWx risks and enhancing STEM education critical for a skilled technical workforce in our nation.

II. PROGRAM DESCRIPTION

The purpose of the Grand Challenges in Integrative Geospace Sciences: Advancing National Space Weather Expertise and Research toward Societal resilience (ANSWERS) solicitation is to support transformative, use-inspired basic research that has the potential to fill key knowledge gaps regarding the integrated Sun-Earth coupled system and space weather, and in combination with forward-looking educational endeavors, to advance the nation's STEM expertise and build societal resilience against space weather hazards.

ANSWERS creates opportunities for collaborations involving solar and geospace observers, theorists, modelers, software developers, and laboratory experimenters as well as experts in STEM education and SWx policy. Proposing teams must have complementary expertise to deal with the full Sun-Earth system and SWx phenomena as well as geospace education. Proposals will be accepted from small teams (up to 6 funded PI, Co-PIs, and senior personnel in total) and large teams. As cultivating future space weather expertise is an important aspect of ANSWERS, teams are strongly encouraged to include researchers within 10 years of PhD in all proposing teams.

Due to the complex, nonlinear interactions between the Sun and geospace, knowledge of the Sun alone or individual components of the geospace system does not imply knowledge or predictability of the whole Sun-to-Earth dynamical phenomenology and SWx. Linear and nonlinear phenomena can affect energetic coupling between geospace layers and may thus impact the response of the larger geospace system to external influences. Elucidating the intricate "sun-to-mud" connections thus qualifies as a grand challenge.

The ANSWERS solicitation entertains compelling, trans-disciplinary research projects in one or more of the following areas:

i. solar and space physics: coupling of solar- and terrestrial forcing or universal processes in the dynamic Sun-Earth system including the Earth's lower atmosphere, at various temporal and spatial scales (transcending latitudes and geospace boundaries); and
ii. space weather and space climate: causes and predictability of phenomena in near-Earth space and their effects on human-built systems and technological infrastructure, resulting in extreme or "everyday" space weather (or storm time vs. quiet time), and their variations between solar minima and maxima.

Possible areas of research could be as focused as understanding particle acceleration and/or transport mechanisms common across the Sun-Earth system, or as broad as predicting space weather using both solar and terrestrial driver inputs. Projects that validate theoretical or model predictions using experimental observations are strongly encouraged.

ANSWERS proposals must formulate and tackle a well-focused scientific problem that is most challenging in geospace sciences and present a coherent, clear, and feasible research plan that builds synergies among, and goes beyond the efforts of, projects supported by existing disciplinary Geospace programs: AER/CEDAR, MAG/GEM, and STR. Proposers may find it useful to consult the 2013 Decadal Survey (https://www.nationalacademies.org/our-work/a-decadal-strategy-for-solar-and-space-physics-heliophysics), GS Portfolio Review (https://www.nsf.gov/geo/adgeo/geospace-review/geospace-portfolio-review-final-rpt-2016.pdf), CEDAR grand challenge workshops or GEM focus groups that highlight some of the most challenging problems in geospace sciences.

Proposals that do not have interdisciplinary collaboration transcending AER/CEDAR, MAG/GEM, or STR program areas will be considered non-responsive to this solicitation. Such proposals should be submitted to the afore-mentioned core or targeted AGS Geospace programs.

Geospace and SWx data are often sparse, patchy, and disparate. ANSWERS supports coordinated community efforts that leverage new or existing observations, analyses of remote-sensing and in-situ data (including both historical and ongoing, high resolution as well synoptic), cross-calibration of multi-point analyses, and application of data-assimilative methodologies in models. Proposers are encouraged to consider the diverse suite of NSF-supported solar and geospace instruments such as solar telescopes and radio heliographs, all-sky imagers, lidars, radars (ISR and SuperDARN), magnetometers, AMPERE, and cubesats. PIs are welcome to propose any particular applications of these facilities and instruments in order to improve understanding of the effects and interactions of various solar- and terrestrial forcing mechanisms and the geo-effectiveness of their impacts. A successful proposal must provide a detailed plan for data sharing and stewardship.

ANSWERS also welcomes proposals that apply new capabilities in high-performance computing, machine learning, artificial intelligence, or uncertainty quantification to deal with grand challenge questions.

A priority for ANSWERS is achieving the strengthening of our Nation's expertise in geospace and SWx, which will increase understanding of the Sun-Earth geospace system and enable development of resilience strategies against SWx hazards. ANSWERS proposals must present clear, compelling broader impacts with a well-planned, strong component of education (formal or informal), stakeholder interaction, and/or public participation in research activities. Educational activities must be motivated by proven geoscience community needs and based on effective practices grounded in STEM education research. ANSWERS teams are strongly encouraged to include specialists drawn from STEM education fields. Proposed activities may include, but are not limited to:

- Curriculum development at the middle school, high school, undergraduate or graduate levels, that creates, shares, and/or leverages physics, astronomy, space science, and mathematics educational products and experiences;
- Technical workforce development;
- Life-long and/or informal learning, and public participation in scientific research.

Competitive proposals must include metrics and evaluation plans for proposed activities in education, workforce training, and public participation in scientific research. Proposers may find it useful to consult, among others, the work of the NSF-funded Center for Advancing the Societal Impacts of Research (https://www.nsf.gov/awardsearch/showAward?AWD_ID=1810732) and the Broader Impacts Guiding Principles and Questions for National Science Foundation Proposals (https://engagementscholarship.org/upload/resources/nabi_guiding_principles-1.pdf).

Solicitation Specific Criteria:

PARTNERSHIPS:

- Co-production of knowledge responsive to the National Space Weather Action Plan, the PROSWIFT Act, and industry-identified user needs is strongly encouraged. Proposers are urged to consider defining science questions in collaboration with stakeholders, e.g., SWx modelers or forecasters, users of SWx information, critical infrastructure owners and operators, and/or emergency management communities. Proposers are encouraged to collaborate with relevant geoscience professional societies or trade associations regarding technical workforce development activities.
- Partnerships with the commercial sector (including for example, electric power, aviation, telecom, satellite industries) to leverage data relevant to advancing SWx research and resilience are encouraged.
- Partnerships between research-intensive and minority-serving institutions are strongly encouraged.

- Links to other NSF investments and NSF-supported Federally Funded Research and Development Centers (FFRDCs) are encouraged, including for example, National Center for Atmospheric Research, National Solar Observatory, as well as NSF Antarctic research investments, among others.

INVOLVEMENT OF DIVERSE AND EARLY-CAREER RESEARCHERS:

- Cultivating the nation's space weather expertise is a primary objective of the ANSWERS solicitation. Full involvement and leadership role for early career researchers and fostering an open and supportive climate for students are essential in all ANSWERS teams.
- Broadening participation in STEM is a priority for NSF. Participation of underrepresented groups in both research and educational aspects is strongly encouraged in all ANSWERS teams, regardless of team size.

III. AWARD INFORMATION

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 4 to 6

Anticipated Funding Amount: $7,500,000

Approximately 2-3 awards each up to $900,000 total over 3 years for SMALL team efforts.

Approximately 2-3 awards each up to $2,500,000 total over up to 4 years for LARGE team efforts.

The budget for a given proposal should be commensurate with the complexity of the proposed research and education efforts.

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds.

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.
- Non-profit, non-academic organizations: Independent museums, observatories, research labs, professional societies and similar organizations in the U.S. associated with educational or research activities.
- For-profit organizations: U.S. commercial organizations, especially small businesses with strong capabilities in scientific or engineering research or education.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

- Although there is no limit on the number of proposals per organization, an organization will only be allowed to receive one ANSWERS award as the lead organization. The organization may also participate in one additional award as a subawardee organization.

Limit on Number of Proposals per PI or Co-PI: 2

- An individual may serve as PI, co-PI, or other senior personnel on no more than two (2) ANSWERS proposals. In cases where an individual appears as senior personnel in more than two proposals, only the first two submitted proposals will be accepted; all other ANSWERS proposals involving that individual will be returned without review.

Additional Eligibility Info:

- Proposals from Minority Serving Institutions are strongly encouraged.
- Researchers at government organizations may participate as senior personnel or collaborators, although no NSF funds will be provided to these organizations.
- Researchers from foreign institutions who contribute essential expertise to the project may participate as collaborators but may not receive NSF support. Proposals including international collaborations must demonstrate how those collaborations enhance the merit of the proposed work by incorporating unique resources, expertise, facilities or sites of international partners. NSF funding should be used only for the U.S. side of the collaboration.

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Full Proposal Preparation Instructions: Proposers may opt to submit proposals in response to this Program Solicitation via Research.gov or Grants.gov.

- Full Proposals submitted via Research.gov: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal and Award Policies and Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg. Paper copies of the PAPPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov. The Prepare New Proposal setup will prompt you for the program solicitation number.
- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov*. The complete text of the *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: (https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov.

In determining which method to utilize in the electronic preparation and submission of the proposal, please note the following:

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via Research.gov. PAPPG Chapter II.D.3 provides additional information on collaborative proposals.

See PAPPG Chapter II.C.2 for guidance on the required sections of a full research proposal submitted to NSF. Please note that the proposal preparation instructions provided in this program solicitation may deviate from the PAPPG instructions.

Proposal Title:

Proposal titles should begin with “ANSWERS:”, then the title.

Supplementary Documentation:

REQUIRED: A separate List of Participants should be provided as a supplementary document.

- At the top of the supplementary document, include “ANSWERS:”, then team size keyword, then title. For LARGE team efforts, it should be ANSWERS: LARGE: Title; for SMALL team efforts, it should be ANSWERS: SMALL: Title. If you submit a proposal as part of a set of collaborative proposals, then use "Collaborative Research: ANSWERS:", then either “LARGE” or “SMALL”, then the title. For example, for LARGE team collaborative proposals, it should be Collaborative Research: ANSWERS: LARGE: Title.

- In a table, list the names and departmental and institution/organization affiliation of all PI, co-PIs, and other Senior Personnel, and unfunded collaborators—both U.S. and international. Summarize in one sentence the role and expertise of each and indicate their approximate time (FTE per year) commitment, regardless of any request for their salary from NSF. Indicate if funded team member is researcher within 10 years of PhD. For collaborative proposals, list all participants collaborating on the project and upload the same list for all (lead and non-lead) submitted proposals.

ENCOURAGED but NOT REQUIRED: Letters of Collaboration, if any, from U.S. subawardees and U.S. or international collaborating institutions may be provided as supplementary documentation and follow the format instructions specified in PAPPG Chapter II.C.2.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Other Budgetary Limitations:

- SMALL team efforts (up to 6 PI, Co-PIs, and senior personnel in total) may request up to $900,000 total over 3 years;
- LARGE team efforts may request up to $2,500,000 total over up to 4 years.

The budget for a given proposal should be commensurate with the complexity of the proposed research and education efforts.

C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

  August 23, 2021

D. Research.gov/Grants.gov Requirements

For Proposals Submitted Via Research.gov:

To prepare and submit a proposal via Research.gov, see detailed technical instructions available at: https://www.research.gov/research-portal/appmanager/base/desktop?

_nfpb=true&_pageLabel=research_node_display&_nodePath=/researchGov/Service/Desktop/ProposalPreparationandSubmission.html. For Research.gov user support, call the Research.gov Help Desk at 1-800-673-6188 or e-mail rgov@nsf.gov. The Research.gov Help Desk answers general technical questions related to the use of the Research.gov system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

For Proposals Submitted Via Grants.gov:

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. Comprehensive information about using Grants.gov is available on the Grants.gov Applicant Resources webpage: https://www.grants.gov/web/grants/applicants.html. In addition, the NSF Grants.gov Application Guide (see link in Section V.A) provides instructions regarding the technical preparation of proposals via Grants.gov. For Grants.gov user support, contact the Grants.gov Contact Center at 1-800-518-4726 or by email: support@grants.gov. The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this solicitation.

Submitting the Proposal: Once all documents have been completed, the Authorized Organizational Representative (AOR) must submit the application to Grants.gov and verify the desired funding opportunity and agency to which the application is submitted. The AOR must then sign and submit the application to Grants.gov. The completed application will be transferred to the NSF FastLane system for further processing.

Proposers that submitted via Research.gov may use Research.gov to verify the status of their submission to NSF. For proposers that submitted via Grants.gov, until an application has been received and validated by NSF, the Authorized Organizational Representative may check the status of an application on Grants.gov. After proposers have received an e-mail notification from NSF, Research.gov should be used to check the status of an application.

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

Proposals received by NSF are assigned to the appropriate NSF program for acknowledgement and, if they meet NSF requirements, for review. All proposals are carefully reviewed by a scientist, engineer, or educator serving as an NSF Program Officer, and usually by three to ten other persons outside NSF either as *ad hoc* reviewers, panelists, or both, who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with oversight of the review process. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal and/or persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Submission of such names, however, is optional. Care is taken to ensure that reviewers have no conflicts of interest with the proposal. In addition, Program Officers may obtain comments from site visits before recommending final action on proposals. Senior NSF staff further review recommendations for awards. A flowchart that depicts the entire NSF proposal and award process (and associated timeline) is included in PAPPG Exhibit III-1.

A comprehensive description of the Foundation's merit review process is available on the NSF website at: https://www.nsf.gov/bfa/dias/policy/merit_review/.

Proposers should also be aware of core strategies that are essential to the fulfillment of NSF's mission, as articulated in *Building the Future: Investing in Discovery and Innovation - NSF Strategic Plan for Fiscal Years (FY) 2018 – 2022*. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

One of the strategic objectives in support of NSF's mission is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions must recruit, train, and prepare a diverse STEM workforce to advance the frontiers of science and participate in the U.S. technology-based economy. NSF's contribution to the national innovation ecosystem is to provide cutting-edge research under the guidance of the Nation's most creative scientists and engineers. NSF also supports development of a strong science, technology, engineering, and mathematics (STEM) workforce by investing in building the knowledge that informs improvements in STEM teaching and learning.

NSF's mission calls for the broadening of opportunities and expanding participation of groups, institutions, and geographic regions that are underrepresented in STEM disciplines, which is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

A. Merit Review Principles and Criteria

The National Science Foundation strives to invest in a robust and diverse portfolio of projects that creates new knowledge and enables breakthroughs in understanding across all areas of science and engineering research and education. To identify which projects to support, NSF relies on a merit review process that incorporates consideration of both the technical aspects of a proposed project and its potential to contribute more broadly to advancing NSF's mission "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense; and for other purposes." NSF makes every effort to conduct a fair, competitive, transparent merit review process for the selection of projects.

1. Merit Review Principles

These principles are to be given due diligence by PIs and organizations when preparing proposals and managing projects, by reviewers when reading and evaluating proposals, and by NSF program staff when determining whether or not to recommend proposals for funding and while overseeing awards. Given that NSF is the primary federal agency charged with nurturing and supporting excellence in basic research and education, the following three principles apply:

- All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge.
- NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the research itself, through activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. The project activities may be based on previously established and/or innovative methods and approaches, but in either case must be well justified.
- Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. If the size of the activity is limited, evaluation of that activity in isolation is not likely to be meaningful. Thus, assessing the effectiveness of these activities may best be done at a higher, more aggregated, level than the individual project.

With respect to the third principle, even if assessment of Broader Impacts outcomes for particular projects is done at an aggregated level, PIs are expected to be accountable for carrying out the activities described in the funded project. Thus, individual projects should include clearly stated goals, specific descriptions of the activities that the PI intends to do, and a plan in place to document the outputs of those activities.

These three merit review principles provide the basis for the merit review criteria, as well as a context within which the users of the criteria can better understand their intent.

2. Merit Review Criteria

All NSF proposals are evaluated through use of the two National Science Board approved merit review criteria. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

The two merit review criteria are listed below. **Both** criteria are to be given **full consideration** during the review and decision-making processes; each criterion is necessary but neither, by itself, is sufficient. Therefore, proposers must fully address both criteria. (PAPPG Chapter II.C.2.d(i). contains additional information for use by proposers in development of the Project Description section of the proposal). Reviewers are strongly encouraged to review the criteria, including PAPPG Chapter II.C.2.d(i), prior to the review of a proposal.

When evaluating NSF proposals, reviewers will be asked to consider what the proposers want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful. These issues apply both to the technical aspects of the proposal and the way in which the project may make broader contributions. To that end, reviewers will be asked to evaluate all proposals against two criteria:

- **Intellectual Merit:** The Intellectual Merit criterion encompasses the potential to advance knowledge; and
- **Broader Impacts:** The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

The following elements should be considered in the review for both criteria:

1. What is the potential for the proposed activity to
    a. Advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and
    b. Benefit society or advance desired societal outcomes (Broader Impacts)?
2. To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?
3. Is the plan for carrying out the proposed activities well-reasoned, well-organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success?
4. How well qualified is the individual, team, or organization to conduct the proposed activities?
5. Are there adequate resources available to the PI (either at the home organization or through collaborations) to carry out the proposed activities?

Broader impacts may be accomplished through the research itself, through the activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. NSF values the advancement of scientific knowledge and activities that contribute to achievement of societally relevant outcomes. Such outcomes include, but are not limited to: full participation of women, persons with disabilities, and other underrepresented groups in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the United States; and enhanced infrastructure for research and education.

Proposers are reminded that reviewers will also be asked to review the Data Management Plan and the Postdoctoral Researcher Mentoring Plan, as appropriate.

Additional Solicitation Specific Review Criteria

All proposals must clearly address the following solicitation-specific review criteria through well-identified proposal elements:

1. How well does the proposed activity address research questions that transcend the NSF AER/CEDAR, MAG/GEM and/or STR program boundaries? Are science challenge questions defined in partnership with space weather users or stakeholders?
2. How diverse is the collaborative team, and do the proposed scientific and broader impact activities provide substantial —including leadership— roles for early-career researchers?

NSF may recruit reviewers who have experience and expertise not only in geospace sciences or space physics but also in STEM education (formal or informal) or policy issues associated with space weather.

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by Ad hoc Review and/or Panel Review.

Reviewers will be asked to evaluate proposals using two National Science Board approved merit review criteria and, if applicable, additional program specific criteria. A summary rating and accompanying narrative will generally be completed and submitted by each reviewer and/or panel. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

After scientific, technical and programmatic review and consideration of appropriate factors, the NSF Program Officer recommends to the cognizant Division Director whether the proposal should be declined or recommended for award. NSF strives to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. Large or particularly complex proposals or proposals from new awardees may require additional review and processing time. The time interval begins on the deadline or target date, or receipt date, whichever is later. The interval ends when the Division Director acts upon the Program Officer's recommendation.

After programmatic approval has been obtained, the proposals recommended for funding will be forwarded to the Division of Grants and Agreements for review of business, financial, and policy implications. After an administrative review has occurred, Grants and Agreements Officers perform the processing and issuance of a grant or other agreement. Proposers are cautioned that only a Grants and Agreements Officer may make commitments, obligations or awards on behalf of NSF or authorize the expenditure of funds. No commitment on the part of NSF should be inferred from technical or budgetary discussions with a NSF Program Officer. A Principal Investigator or organization that makes financial or personnel commitments in the absence of a grant or cooperative agreement

signed by the NSF Grants and Agreements Officer does so at their own risk.

Once an award or declination decision has been made, Principal Investigators are provided feedback about their proposals. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers or any reviewer-identifying information, are sent to the Principal Investigator/Project Director by the Program Officer. In addition, the proposer will receive an explanation of the decision to award or decline funding.

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

Notification of the award is made to *the submitting organization* by a Grants Officer in the Division of Grants and Agreements. Organizations whose proposals are declined will be advised as promptly as possible by the cognizant NSF Program administering the program. Verbatim copies of reviews, not including the identity of the reviewer, will be provided automatically to the Principal Investigator. (See Section VI.B. for additional information on the review process.)

B. Award Conditions

An NSF award consists of: (1) the award notice, which includes any special provisions applicable to the award and any numbered amendments thereto; (2) the budget, which indicates the amounts, by categories of expense, on which NSF has based its support (or otherwise communicates any specific approvals or disapprovals of proposed expenditures); (3) the proposal referenced in the award notice; (4) the applicable award conditions, such as Grant General Conditions (GC-1)*; or Research Terms and Conditions* and (5) any announcement or other NSF issuance that may be incorporated by reference in the award notice. Cooperative agreements also are administered in accordance with NSF Cooperative Agreement Financial and Administrative Terms and Conditions (CA-FATC) and the applicable Programmatic Terms and Conditions. NSF awards are electronically signed by an NSF Grants and Agreements Officer and transmitted electronically to the organization via e-mail.

*These documents may be accessed electronically on NSF's Website at https://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 or by e-mail from nsfpubs@nsf.gov.

More comprehensive information on NSF Award Conditions and other important information on the administration of NSF awards is contained in the NSF *Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

C. Reporting Requirements

For all multi-year grants (including both standard and continuing grants), the Principal Investigator must submit an annual project report to the cognizant Program Officer no later than 90 days prior to the end of the current budget period. (Some programs or awards require submission of more frequent project reports). No later than 120 days following expiration of a grant, the PI also is required to submit a final project report, and a project outcomes report for the general public.

Failure to provide the required annual or final project reports, or the project outcomes report, will delay NSF review and processing of any future funding increments as well as any pending proposals for all identified PIs and co-PIs on a given award. PIs should examine the formats of the required reports in advance to assure availability of required data.

PIs are required to use NSF's electronic project-reporting system, available through Research.gov, for preparation and submission of annual and final project reports. Such reports provide information on accomplishments, project participants (individual and organizational), publications, and other specific products and impacts of the project. Submission of the report via Research.gov constitutes certification by the PI that the contents of the report are accurate and complete. The project outcomes report also must be prepared and submitted using Research.gov. This report serves as a brief summary, prepared specifically for the public, of the nature and outcomes of the project. This report will be posted on the NSF website exactly as it is submitted by the PI.

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

VIII. AGENCY CONTACTS

Please note that the program contact information is current at the time of publishing. See program website for any updates to the points of contact.

General inquiries regarding this program should be made to:

- Mangala Sharma, Program Director, Space Weather Research, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov
- Zhuangren (Alan) Liu, Program Director, Aeronomy/CEDAR, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov
- Ilia I. Roussev, Program Director, Solar Terrestrial research/SHINE, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov
- Lisa M. Winter, Program Director, Magnetospheric Physics/GEM, telephone: (703) 292-8519, email: IntegrativeGeospace@nsf.gov

For questions related to the use of FastLane or Research.gov, contact:

- FastLane and Research.gov Help Desk: 1-800-673-6188
- FastLane Help Desk e-mail: fastlane@nsf.gov.
- Research.gov Help Desk e-mail: rgov@nsf.gov

For questions relating to Grants.gov contact:

- Grants.gov Contact Center: If the Authorized Organizational Representatives (AOR) has not received a confirmation message from Grants.gov within 48 hours of submission of application, please contact via telephone: 1-800-518-4726; e-mail: support@grants.gov.

IX. OTHER INFORMATION

The NSF website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this website by potential proposers is strongly encouraged. In addition, "NSF Update" is an information-delivery system designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF Grants Conferences. Subscribers are informed through e-mail or the user's Web browser each time new publications are issued that match their identified interests. "NSF Update" also is available on NSF's website.

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding opportunities may be accessed via this mechanism. Further information on Grants.gov may be obtained at https://www.grants.gov.

ABOUT THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent Federal agency created by the National Science Foundation Act of 1950, as amended (42 USC 1861-75). The Act states the purpose of the NSF is "to promote the progress of science; [and] to advance the national health, prosperity, and welfare by supporting research and education in all fields of science and engineering."

NSF funds research and education in most fields of science and engineering. It does this through grants and cooperative agreements to more than 2,000 colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations throughout the US. The Foundation accounts for about one-fourth of Federal support to academic institutions for basic research.

NSF receives approximately 55,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded. In addition, the Foundation receives several thousand applications for graduate and postdoctoral fellowships. The agency operates no laboratories itself but does support National Research Centers, user facilities, certain oceanographic vessels and Arctic and Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US participation in international scientific and engineering efforts, and educational activities at every academic level.

Facilitation Awards for Scientists and Engineers with Disabilities (FASED) provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See the *NSF Proposal & Award Policies & Procedures Guide* Chapter II.E.6 for instructions regarding preparation of these types of proposals.

The National Science Foundation has Telephonic Device for the Deaf (TDD) and Federal Information Relay Service (FIRS) capabilities that enable individuals with hearing impairments to communicate with the Foundation about NSF programs, employment or general information. TDD may be accessed at (703) 292-5090 and (800) 281-8749, FIRS at (800) 877-8339.

The National Science Foundation Information Center may be reached at (703) 292-5111.

The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at https://www.nsf.gov

- **Location:** 2415 Eisenhower Avenue, Alexandria, VA 22314
- **For General Information** (NSF Information Center)**:** (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**

  Send an e-mail to: nsfpubs@nsf.gov

  or telephone: (703) 292-8134
- **To Locate NSF Employees:** (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

The information requested on proposal forms and project reports is solicited under the authority of the National Science Foundation Act of 1950, as amended. The information on proposal forms will be used in connection with the selection of qualified proposals; and project reports submitted by awardees will be used for program evaluation and reporting within the Executive Branch and to Congress. The information requested may be disclosed to qualified reviewers and staff assistants as part of the proposal review process; to proposer institutions/grantees to provide or obtain data regarding the proposal review process, award decisions, or the administration of awards; to government contractors, experts, volunteers and researchers and educators as necessary to complete assigned work; to other government agencies or other entities needing information regarding applicants or nominees as part of a joint application review process, or in order to coordinate programs or policy; and to another Federal agency, court, or party in a court or Federal administrative proceeding if the government is a party. Information about Principal Investigators may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See System of Record Notices, NSF-50, "Principal Investigator/Proposal File and Associated Records," and NSF-51, "Reviewer/Proposal File and Associated Records." Submission of the information is voluntary. Failure to provide full and complete information, however, may reduce the possibility of receiving an award.

An agency may not conduct or sponsor, and a person is not required to respond to, an information collection unless it displays a valid Office of Management and Budget (OMB) control number. The OMB control number for this collection is 3145-0058. Public reporting burden for this collection of information is estimated to average 120 hours per response, including the time for reviewing instructions. Send comments regarding the burden estimate and any other aspect of this collection of information, including suggestions for reducing this burden, to:

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