

Transdisciplinary Research in Principles of Data Science Phase I (TRIPODS)

TRIPODS Phase I

PROGRAM SOLICITATION

NSF 16-615



National Science Foundation

Directorate for Computer & Information Science & Engineering
Division of Computing and Communication Foundations

Directorate for Mathematical & Physical Sciences
Division of Mathematical Sciences

Letter of Intent Due Date(s) (required) (due by 5 p.m. submitter's local time):

January 04, 2017 - January 19, 2017

This window is for Letters of Intent. See Proposal Preparation and Submission Instructions below.

Submission Window Date(s) (due by 5 p.m. submitter's local time):

March 01, 2017 - March 15, 2017

This window is for Full Proposals. See Proposal Preparation and Submission Instructions below.

IMPORTANT INFORMATION AND REVISION NOTES

Letters of Intent submitted in response to this solicitation should be submitted in accordance with the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) ([NSF 16-1](#)).

Full Proposals submitted in response to this solicitation should be submitted in accordance with the revised NSF PAPPG (NSF 17-1). NSF anticipates release of the PAPPG in the Fall of 2016 and it will be effective for proposals submitted, or due, on or after January 30, 2017.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Transdisciplinary Research in Principles of Data Science (TRIPODS)

Synopsis of Program:

Transdisciplinary Research In Principles Of Data Science (TRIPODS) aims to bring together the statistics, mathematics, and theoretical computer science communities to develop the theoretical foundations of data science through integrated research and training activities. Phase I, described in this solicitation, will support the development of small collaborative Institutes. Phase II (to be described in an anticipated future solicitation, subject to availability of funds) will support a smaller number of larger Institutes, selected from the Phase I Institutes via a second competitive proposal process. All TRIPODS Institutes must involve significant and integral participation by all three of the aforementioned communities.

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.

- Nandini Kannan, Program Director, Division of Mathematical Sciences, telephone: (703) 292-8104, email: tripods@nsf.gov
- Tracy Kimbrel, Program Director, Division of Computing and Communication Foundations, telephone: (703) 292-8910, email: tripods@nsf.gov
- Jack Snoeyink, Program Director, Division of Computing and Communication Foundations, telephone: (703) 292-8910, email: tripods@nsf.gov
- Christopher W. Stark, Program Director, Division of Mathematical Sciences, telephone: (703) 292-4869, email: tripods@nsf.gov
- Chaitanya Baru, Senior Advisor for Data Science, Directorate for Computer and Information Science and Engineering,

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

- 47.049 --- Mathematical and Physical Sciences
- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award: Continuing Grant

Estimated Number of Awards: 8 to 10

Eight to ten awards of \$1,200,000 to \$1,500,000 per award are anticipated. The number of awards will be subject to availability of funds and receipt of proposals of adequate quality.

Anticipated Funding Amount: \$12,000,000

Proposers may request up to \$500,000 per year for a duration of three years.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Universities or four-year colleges accredited in and having a campus located in the United States, or nonprofit, nonacademic organizations in the US associated with educational or research activities. Multi-institutional consortia are permitted, but a single entity must accept overall management responsibility.

Who May Serve as PI:

PI teams must collectively possess appropriate expertise in all of the three relevant disciplines. It is anticipated that in most cases this requirement will be met by assembling teams of three or more individuals. Teams may be composed of members at multiple institutions or a single institution.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An individual may serve as PI or co-PI on at most one project team, but may serve as other Senior Personnel on any number of teams. In the event that an individual exceeds the PI or co-PI limit, proposals will be accepted based on earliest date and time of proposal submission, i.e., the first proposal will be accepted and the remainder will be returned without review. **No exceptions will be made.**

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Submission of Letters of Intent is required. Please see the full text of this solicitation for further information.
- **Preliminary Proposal Submission:** Not required
- **Full Proposals:**
 - Full Proposals submitted via FastLane: *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=papp.
 - 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: http://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:**

Not Applicable

C. Due Dates

- **Letter of Intent Due Date(s) (required)** (due by 5 p.m. submitter's local time):

January 04, 2017 - January 19, 2017

This window is for Letters of Intent. See Proposal Preparation and Submission Instructions below.

- **Submission Window Date(s)** (due by 5 p.m. submitter's local time):

March 01, 2017 - March 15, 2017

This window is for Full Proposals. See Proposal Preparation and Submission Instructions below.

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria. Additional merit review considerations 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

Technological advances, coupled with unprecedented access to computing infrastructure, have resulted in an explosion in the availability of data from disparate sources. The National Science Foundation recently released a document, *10 Big Ideas for Future NSF Investments* (see https://www.nsf.gov/about/congress/reports/nsf_big_ideas.pdf), that seeks to "define a set of cutting-edge research agendas and processes." One of the Big Ideas is *Harnessing Data for 21st Century Science and Engineering*, described as "a bold initiative to develop a cohesive, national-scale approach to research data infrastructure and a 21st-century workforce capable of working effectively with data."

The document goes on to make the following points:

- The increasing speed at which we collect data, as well as the increasing volume and variety of that data, are profoundly transforming research in all fields of Science and Engineering (S&E).
- This initiative will support basic research in mathematics, statistics and computer science that will enable data-driven discovery through visualization, better data mining, machine learning and more.

The Division of Computing and Communication Foundations (CCF) in the Directorate for Computer & Information Science &

Engineering (CISE) and the Division of Mathematical Sciences (DMS) in the Directorate for Mathematical and Physical Sciences (MPS) recognize the need for investments in data science, an important interdisciplinary field with significant impacts spanning many aspects of the modern world, including across government, industry, academia, and the general public. While there have been significant investments related to the National Big Data Research and Development Initiative [see, for example, the Critical Techniques, Technologies and Methodologies for Advancing Foundations and Applications of Big Data Sciences and Engineering (BIGDATA), at http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504767], they have not focused specifically on foundational principles. The TRIPODS program seeks to support research and training activities focused on the theoretical foundations of data science, i.e., the core algorithmic, mathematical, and statistical principles.

In April 2016, DMS and CCF sponsored a workshop *Theoretical Foundations of Data Science (TFoDS): Algorithmic, Mathematical, and Statistical* (see <http://www.cs.rpi.edu/TFoDS/>) that assembled leading researchers representing the three core disciplines of computer science, mathematics, and statistics. A draft report is available at http://www.cs.rpi.edu/TFoDS/TFoDS_v5.pdf. A key conclusion of the report is that “*theoretical foundations are necessary in all aspects of data science, from the generation and collection of data to the analysis and decision making processes.*”

The report further states:

“TFoDS will be intrinsically interdisciplinary, in the sense that many different scientific domains will need to work together and develop novel theories that transcend disciplinary boundaries. Particular emphasis should be placed on interdisciplinary collaborations between computer scientists, mathematicians, and statisticians, since these three disciplines are at the heart of TFoDS.”

Recognizing the need to engage these communities and foster collaborations, CCF and DMS are joining together to develop this new program with the goal of promoting long-term, interdisciplinary research and training activities that engage computer scientists, statisticians, and mathematicians in developing the theoretical foundations of data science.

II. PROGRAM DESCRIPTION

Phase I of the *Transdisciplinary Research In Principles Of Data Science* (TRIPODS) program will support the development of small collaborative Institutes that will bring together the three disciplines. Proposals must address fundamental research and training in the theoretical foundations of data science, and describe the significant involvement of all three communities.

Program and project structures

The TRIPODS program is anticipated to consist of two phases, subject to availability of funds. In Phase I (represented by this solicitation), the program will support approximately eight TRIPODS Institutes for a duration of three years, each at a planned level of up to \$500,000 per year. Approximately two years after Phase I awards are made, a solicitation for Phase II proposals for larger Institutes is anticipated. Phase II will potentially support a smaller number of Institutes at a significantly higher level of funding for a duration of five years, subject to availability of funds. Institutes will be encouraged to seek additional support from other sources, such as industrial partners. In the anticipated Phase II, CCF and DMS may elect to provide partial matching incentives for such additional support (subject to availability of funds).

Phase I awards are intended to allow teams to develop capacity and demonstrate the ability to scale activities for full Institute operations by operating as smaller Institutes. While novel approaches are encouraged, it is anticipated that traditional center-like activities will be common, including but not limited to (in no particular order):

- integration of research and education including the definition and development of data science curricula;
- workforce development strategies in the emerging field of data science;
- short- and medium-term collaborative gatherings of leading and early-career scientists;
- longer-term visits;
- participation in research activities by and professional training opportunities for graduate students and postdoctoral fellows; and
- direction-setting for research agendas.

While we anticipate that most or all of these activities (and more) will be included in Phase II Institutes, a Phase I Institute may choose to focus its efforts on a smaller set of activities. Ongoing assessment of an Institute's programs and activities, in preparation for a potential Phase II, will be critical; see "Proposal Preparation and Submission Instructions" and "Additional Solicitation Specific Review Criteria" below.

Coordination, cooperation, and collaboration among the Institutes during Phase I are encouraged. We also encourage Institutes to consider coalescing into larger teams for the anticipated Phase II competition, combining complementary strengths exhibited and developed in Phase I. However, we emphasize that all three of the targeted disciplines must be represented in each Phase I Institute. Competitive Phase I proposals will comprise teams with at least one PI or co-PI from each targeted discipline. To be eligible to submit a proposal for a potential Phase II Institute, it is anticipated that at least one PI or co-PI will need to be a PI or co-PI of a funded Phase I Institute.

We encourage Institutes to leverage existing NSF investments such as [Big Data Regional Innovation Hubs](#), [Mathematical Sciences Research Institutes](#), and [Software Infrastructure for Sustained Innovation](#) as appropriate through collaborations or partnerships.

Annual PI meetings will be held in the Washington, DC, area to help facilitate the collaboration and cooperation mentioned previously. At least two team members from each Institute must plan to attend, and proposal budgets must include appropriate amounts for travel to the Washington, DC, area once each year.

Broad themes of the program

Proposals for TRIPODS Institutes should demonstrate plans to address the following important factors (drawn in part from the TFoDS Workshop report):

- Different communities, such as those that developed business, Internet, and social media applications and those that

developed scientific and medical applications, and, indeed, the computer science, statistics, and mathematics communities, have developed different terminology and formalisms for overlapping concepts and methods. Overcoming these barriers will be crucial for success.

- Algorithms developed for theoretical purposes without good knowledge of application domains will typically fail to take into account peculiarities and incompleteness properties of real data, and this failure will limit their impact.
- While the scientific focus must be on the theoretical foundations, relevance to application domains and industry is important. Effective communication mechanisms will be required to make these stakeholders aware of what the TRIPODS community can offer, and early engagement with these communities is encouraged.
- Data science is already a reality in industrial and scientific enterprises and there is ever-increasing demand from students to get more training in this field. A remarkable aspect of data science is that many research communities and traditional fields of study identify with the term. However, each field has different interpretations for this concept. Unified curricula for data science should be developed in cognizance of this.
- It will be a challenge to fit the necessary foundations from statistics, computer science, and mathematics into a curriculum for data science. On top of these foundations, experimental validation, ethical behavior, and interdisciplinary communication skills (for communication across the three underlying fields as well as with application domains) will be vital components of curricula.
- Data science ranges from experimental design and data collection all the way to data analysis and the final decision-making, i.e., the entire “data to knowledge to action” pipeline. Data provenance, reproducibility, privacy, and algorithmic fairness are all fundamental topics that Institutes should actively investigate. These areas are important for foundational research to make impacts beyond academic environments.
- Data science is iterative, with a dynamic feedback loop. Targets can change as more data are acquired; instead of limiting attention to idealized systems under restrictive assumptions, dynamic data collection is general, heterogeneous, and messy. Many existing tools of mathematics, statistics, and theoretical computer science are not equipped to handle this aspect of data science problems.

In addition to the factors above, proposers should identify and justify further elements of the foundations of data science that they deem to be critical.

Sample specific research topics

Fundamental research areas that may be a part of the focus of a transdisciplinary collaboration under this solicitation include, but are not limited to:

- Combinatorial inference on complex structures;
- Tradeoffs between computational costs and statistical efficiency;
- Randomized numerical linear algebra;
- Representation theory and non-commutative harmonic analysis;
- Topological data analysis (TDA) and homological algebra; and
- Multiple areas in machine learning including deep learning.

While this list is not meant to be exhaustive or exclusive, proposals must exemplify the roles of the mathematics, theoretical computer science, and statistics communities in laying theoretical foundations for data science, and bring about a true synergy of the best capabilities of all three disciplines.

III. AWARD INFORMATION

Anticipated Type of Award: Continuing Grant

Estimated Number of Awards: 8 to 10

Eight to ten awards of \$1,200,000 to \$1,500,000 per award are anticipated. The number of awards will be subject to availability of funds and receipt of proposals of adequate quality.

Anticipated Funding Amount: \$12,000,000

Proposers may request up to \$500,000 per year for a duration of three years.

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:

- Universities or four-year colleges accredited in and having a campus located in the United States, or nonprofit, nonacademic organizations in the US associated with educational or research activities. Multi-institutional consortia are permitted, but a single entity must accept overall management responsibility.

Who May Serve as PI:

PI teams must collectively possess appropriate expertise in all of the three relevant disciplines. It is anticipated that in most cases this requirement will be met by assembling teams of three or more individuals. Teams may be composed of members at multiple institutions or a single institution.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An individual may serve as PI or co-PI on at most one project team, but may serve as other Senior Personnel on any number of teams. In the event that an individual exceeds the PI or co-PI limit, proposals will be accepted based on earliest date and time of proposal submission, i.e., the first proposal will be accepted and the remainder will be returned without review. **No exceptions will be made.**

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Letters of Intent (required):

Potential proposers may not submit a full proposal without first submitting a corresponding Letter of Intent (LOI), compliant with the instructions below, during the LOI submission window. Submitting a Letter of Intent does not oblige potential proposers to submit a full proposal. If a collaborative proposal is planned, a single LOI should be submitted by the lead institution only. LOIs are not subject to merit review but instead are used for internal planning purposes. Investigators should not expect to receive any feedback on their LOIs.

Each LOI must include the following information:

In the Synopsis section, include a brief overview of the plans to develop a TRIPODS Institute.

In the Project PI and Senior Personnel section, list the full names and institutional affiliations for all PIs, Co-PIs, and senior personnel on the planned project, including all collaborative proposals and subawardees. The point of contact for NSF inquiries must be the same as the project PI, with the project PI's e-mail address specified.

In the Participating Organizations section, list all of the institutions involved in the planned project.

If the Project PI and Senior Personnel and Participating Organizations sections do not provide enough space, continuations may be entered in the Other Comments section.

Letter of Intent Preparation Instructions:

When submitting a Letter of Intent through FastLane in response to this Program Solicitation please note the conditions outlined below:

- Submission by an Authorized Organizational Representative (AOR) is not required when submitting Letters of Intent.
- A Minimum of 0 and Maximum of 4 Other Senior Project Personnel are allowed
- A Minimum of 0 and Maximum of 4 Other Participating Organizations are allowed
- Submission of multiple Letters of Intent is allowed

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

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal & Award Policies & 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) 292-7827 or by e-mail from nsfpubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.
- 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: (http://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) 292-7827 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 the NSF FastLane system. PAPPG Chapter II.C.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.

Project Description

The Project Description should include an **overall timeline of activities and milestones**, and should indicate how the Institute will **develop capacity and capability for full operations** in a potential Phase II.

Supplementary Documents

Each proposal is required to include a **Collaboration and Evaluation Plan** as a separate supplementary document (limited to 5 pages). This plan must describe the **expertise in the three disciplines** provided by the PIs as required above under "Who May Serve as PI" as well as plans for working together to meet the goals of the program. The Collaboration and Evaluation Plan must also describe **clear measures of success** for the project, including developing capability and capacity for a potential Phase II, and a plan for **evaluating success**. **Proposals without this document will be returned without review.**

Single Copy Documents

Collaborators and Other Affiliations Information:

For this solicitation, the *Collaborators & Other Affiliations* information specified in the PAPPG should be submitted using the spreadsheet template found at <https://www.nsf.gov/cise/collab/>. For each proposal, a completed spreadsheet for each PI, co-PI, or senior personnel must be uploaded directly into Fastlane in .xls or .xlsx format as a "Collaborator and Other Affiliations" Single Copy Document. NSF staff use this information in the merit review process to help manage reviewer selection; the spreadsheet will ensure the Collaborator and Other Affiliations information has a common, searchable format.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Budget Preparation Instructions:

Budgets for all projects must include travel funding for at least two team members to attend annual TRIPODS PI meetings during the proposed lifetime of the award. For budget preparation purposes, PIs may assume these meetings will be held in the Washington, DC, area.

C. Due Dates

- **Letter of Intent Due Date(s) (required)** (due by 5 p.m. submitter's local time):

January 04, 2017 - January 19, 2017

This window is for Letters of Intent. See Proposal Preparation and Submission Instructions below.

- **Submission Window Date(s)** (due by 5 p.m. submitter's local time):

March 01, 2017 - March 15, 2017

This window is for Full Proposals. See Proposal Preparation and Submission Instructions below.

D. FastLane/Grants.gov Requirements

For Proposals Submitted Via FastLane:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: <https://www.fastlane.nsf.gov/a1/newstan.htm>. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov. The FastLane Help Desk answers general technical questions related to the use of the FastLane 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: <http://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 FastLane are strongly encouraged to use FastLane 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: http://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 *Investing in Science, Engineering, and Education for the Nation's Future: NSF Strategic Plan for 2014-2018*. 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 underrepresented minorities 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

- a. Does the proposal describe a well-integrated research and training program focused on the theoretical foundations of data science and fostering collaboration and interaction among the three communities of TRIPODS – mathematics, statistics, and theoretical computer science?
- b. Does the proposal address the “broad themes of the program” listed in the Program Description?
- c. Does the proposal address strategies for workforce development, including novel educational and training activities?
- d. Transdisciplinarity/Synergy: Is the project transdisciplinary, bringing together theories and approaches from theoretical computer science, mathematics, and statistics? Is there synergy between the different groups?
- e. Vision: Is there a strong case for the ability to identify and articulate a vision for the foundations of data science?
- f. Quality and Value of Collaboration: Is the expertise of the PIs complementary and well-suited to the research and training programs developed in this project? Are the specific roles of each collaborating investigator clear? Does the collective team have expertise representing the three communities (statistics, mathematics, and theoretical computer science)?
- g. Is there a well-developed plan for communication and interaction with the domain sciences and industry?
- h. Does the proposal provide a clear plan and rationale for an investment of the size proposed, including clear plans to develop capacity for potential future Phase II operations?
- i. Does the Collaboration and Evaluation Plan identify clear measures of success, both for Phase I operations and development of capability for a potential Phase II, along with a plan to evaluate the project with respect to those measures by gathering quantitative and qualitative data?
- j. Does the Collaboration and Evaluation Plan provide a clear plan for thoughtful, ongoing assessment of all Institute activities? How will the assessment be used to inform and improve both daily Institute operations and long range planning, aiming toward a successful Phase II Institute?

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 http://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 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=papp.

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=papp.

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:

- Nandini Kannan, Program Director, Division of Mathematical Sciences, telephone: (703) 292-8104, email: tripods@nsf.gov
- Tracy Kimbrel, Program Director, Division of Computing and Communication Foundations, telephone: (703) 292-8910, email: tripods@nsf.gov
- Jack Snoeyink, Program Director, Division of Computing and Communication Foundations, telephone: (703) 292-8910, email: tripods@nsf.gov

- Christopher W. Stark, Program Director, Division of Mathematical Sciences, telephone: (703) 292-4869, email: tripods@nsf.gov
- Chaitanya Baru, Senior Advisor for Data Science, Directorate for Computer and Information Science and Engineering, telephone: (703) 292-4541, email: tripods@nsf.gov

For questions related to the use of FastLane, contact:

- FastLane Help Desk, telephone: 1-800-673-6188; e-mail: fastlane@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 <http://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 (FASSED) 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 <http://www.nsf.gov>

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(NSF Information Center): | (703) 292-5111 |
| • TDD (for the hearing-impaired): | (703) 292-5090 |
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| or telephone: | (703) 292-7827 |
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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 Systems of Records, [NSF-50](#), "Principal Investigator/Proposal File and Associated Records," 69 Federal Register 26410 (May 12, 2004), and [NSF-51](#), "Reviewer/Proposal File and Associated Records," 69 Federal Register 26410 (May 12, 2004). 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:

Suzanne H. Plimpton
Reports Clearance Officer
Office of the General Counsel
National Science Foundation
Arlington, VA 22230

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