

# Ideas Lab: Practical Fully-Connected Quantum Computer Challenge (PFCQC)

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## PROGRAM SOLICITATION

NSF 17-548

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### REPLACES DOCUMENT(S):

NSF 16-520

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#### National Science Foundation

Directorate for Mathematical & Physical Sciences  
Division of Physics

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

Directorate for Engineering  
Division of Electrical, Communications and Cyber Systems

**Preliminary Proposal Due Date(s) (required)** (due by 5 p.m. submitter's local time):

June 19, 2017

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

November 30, 2017

## IMPORTANT INFORMATION AND REVISION NOTES

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Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 17-1), which is effective for proposals submitted, or due, on or after January 30, 2017.

## SUMMARY OF PROGRAM REQUIREMENTS

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### General Information

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#### Program Title:

Ideas Lab: Practical Fully-Connected Quantum Computer Challenge (PFCQC)

#### Synopsis of Program:

Quantum computing is a revolutionary approach to information processing based on the quantum physics of coherent superposition and entanglement. Advantages of quantum computing include efficient algorithms for computationally difficult tasks, efficient use of resources such as memory and energy needed for computations, and new platforms for the simulation of quantum mechanical systems that are currently intractable using conventional computers. Applications for quantum computing, such as integer number factoring, search and optimization algorithms, and quantum simulations, will accelerate discoveries in a broad range of disciplines including physics, engineering, and computer science.

The task of building a practical quantum computer remains a Grand Challenge<sup>1,2</sup>. To demonstrate a practical-scale quantum computer, advances are needed in several domains, including device fabrication, quantum control, new physical-level architectures, implementation of error correction and decoherence-avoiding strategies, compilation of quantum programs, programming of quantum computers, software to operate quantum computers, and quantum algorithm design. A co-design approach to integrating hardware, software, and quantum algorithms, adapted to the specific characteristics of the quantum-computing platform being developed, is needed to achieve quantum-computing capabilities beyond the classical computing limit and deliver on the promise of quantum computing.

This solicitation describes an Ideas Lab focused on the Practical Fully-Connected Quantum Computer (PFCQC) challenge. Ideas Labs are intensive meetings that bring together multiple diverse perspectives to focus on finding innovative cross-disciplinary solutions to grand challenge problems. The ultimate aim of this Ideas Lab is to facilitate

the development and operation of a practical-scale quantum computer. The aspiration is that bringing together researchers from diverse scientific backgrounds will engender fresh thinking and innovative approaches that will provide a fertile ground for new ideas on the design and fabrication of quantum devices and processors and implementation of quantum information processing algorithms. This will enable the solution of science problems that are currently beyond the reach of modern high-performance computing applications on classical computers. U.S. researchers may submit preliminary proposals for participation in the Ideas Lab only via FastLane. The goal is to form teams of domain scientists and engineers that will develop multidisciplinary ideas that eventually will be submitted as full proposals.

This Ideas Lab advances the objectives of two of *10 Big Ideas for Future NSF Investments*: "The Quantum Leap: Leading the Next Quantum Revolution" and "Growing Convergent Research at NSF". The 10 big ideas will push forward the frontiers of U.S. research, provide innovative approaches to solve some of the most pressing problems the world faces, as well as lead to discoveries not yet known. This Ideas Lab also advances the third objective of the National Strategic Computing Initiative (NSCI), an effort aimed at developing new technological capabilities in the post-Moore's Law era.

This Ideas Lab is organized by the Division of Physics (PHY) in the Directorate for Mathematical and Physical Sciences (MPS), the Division of Computing and Communication Foundations (CCF) in the Directorate for Computer and Information Science and Engineering (CISE), and the Division of Electrical, Communications and Cyber Systems (ECCS) in the Directorate for Engineering (ENG).

#### References

1. "Controlling the Quantum World: The Science of Atoms, Molecules, and Photons," National Research Council, 2007
2. "Advancing Quantum Information Science: National Challenges and Opportunities," Report of the National Science and Technology Council, 2016

#### 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.

- Bogdan Mihaila, telephone: (703) 292-8235, email: [bmihaila@nsf.gov](mailto:bmihaila@nsf.gov)
- Almadena Y. Chitchelkanova, telephone: (703) 292-8910, email: [achtchel@nsf.gov](mailto:achtchel@nsf.gov)
- Akbar Sayeed, telephone: (703) 292-4753, email: [asayeed@nsf.gov](mailto:asayeed@nsf.gov)

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

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

## Award Information

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**Anticipated Type of Award:** Standard Grant or Continuing Grant or Cooperative Agreement

**Estimated Number of Awards:** 1 to 2

Estimated program budget and average award size/duration is subject to availability of funds. A PFCQC award is expected to be at the level of \$1,000,000 – \$3,000,000 per year. Up to 2 awards are expected in FY 2018 depending upon availability of funds and the type, scale, and variety of project ideas developed at the Ideas Lab.

**Anticipated Funding Amount:** \$5,000,000 to \$15,000,000

The total funding available for awards stemming from full proposals that will be developed in the Ideas Lab will total up to \$5,000,000 to \$15,000,000 for 5 years, with up to \$1,000,000 to \$3,000,000 in FY 2018, pending availability of funds and compelling proposals.

## Eligibility Information

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#### Who May Submit Proposals:

The categories of proposers eligible to submit proposals to the National Science Foundation are identified in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG), Chapter I.E.

#### Who May Serve as PI:

There are no restrictions or limits.

#### Limit on Number of Proposals per Organization:

There are no restrictions or limits.

#### Limit on Number of Proposals per PI or Co-PI: 1

## Proposal Preparation and Submission Instructions

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### A. Proposal Preparation Instructions

- **Letters of Intent:** Not required
- **Preliminary Proposals:** Submission of Preliminary Proposals is required. Please see the full text of this solicitation for further information.
- **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=pappg](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](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:**

Not Applicable

### C. Due Dates

- **Preliminary Proposal Due Date(s) (required)** (due by 5 p.m. submitter's local time):

June 19, 2017
- **Full Proposal Deadline(s)** (due by 5 p.m. submitter's local time):

November 30, 2017

## Proposal Review Information Criteria

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### 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

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### Award Conditions:

Standard NSF award conditions apply.

### Reporting Requirements:

Standard NSF reporting requirements apply.

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## I. INTRODUCTION

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This solicitation seeks projects able to deliver a practical-scale quantum computer using fully-connected physical qubits. PFCQC projects are expected to demonstrate significant improvement in performance over current state-of-the-art quantum computer realizations. It is anticipated that the successful project will require the integration of several layers, from hardware to software to applications, using a co-design approach. In turn, the co-design approach will require experts spanning device and system engineering, physics, computer science, and information theory.

The successful PFCQC project will deliver a functional quantum information-processing system that exceeds the capabilities of a classical computer and includes co-designed algorithms, software, control elements, physical architecture, interconnects, and device manufacturing capabilities. A successful proposal will realize an end-to-end system that integrates the following components:

- Applications:
  - **Adapt**: applications to machine architecture and scale
  - **Design**: algorithm design and quantum circuitry development
  - **Quantum algorithms**: factoring, search, and optimization algorithms; quantum simulations
- Software:
  - **User interface**: efficient, user-friendly interaction with the quantum processors
  - **Quantum compiler**: translate algorithms, adapt them to machine architecture
  - **Cost-based metrics optimization**: qubits-used count, gate count, runtime, fidelity, energy use
  - **Quantum control**: state initialization, gate operations, readouts
- Hardware:
  - **Physics**: physical qubits, quantum control
  - **Devices**: on-chip integration of qubit entanglement, gate operations, and quantum control
  - **Systems engineering**: architecture, interconnects
- Quality Control:
  - **Benchmarking**: application-specific and system benchmarks

The above examples are intended to be illustrative, not exhaustive. Participation in the Ideas Lab requires an invitation in response to a preliminary proposal. Submission of a full proposal derived from the Ideas Lab requires both participation in the Ideas Lab and an invitation to submit a full proposal. Full proposals derived from the Ideas Lab must include ideas that can lead to a step-change, rather than incremental advances, in our knowledge.

## II. PROGRAM DESCRIPTION

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The Ideas Lab is an interactive gathering on a focused problem and typically involves up to 30 participants. This Ideas Lab aims to stimulate thinking in promising new techniques to develop and operate a practical-scale fully-connected quantum computer to demonstrate significant progress over current state-of-the-art.

Participants will be expected to engage constructively in dialogue with one another, the facilitators, and the Director(s) and mentors to develop collaborative research proposals. Collaboration is an integral aspect of the activity.

How will the Ideas Lab Work? The Ideas Lab is an intensive, interactive and free-thinking environment, where a diverse group of participants from a range of disciplines and backgrounds gets together for five days - away from their everyday worlds - to immerse themselves in collaborative thinking processes in order to construct innovative approaches. The Ideas Lab will run over five days starting mid-morning on Day One and finishing mid-afternoon on Day Five. At the outset, the participants will work collaboratively to identify and define the scope of the research and engineering challenges relating to the development and operation of a practical fully-connected quantum computer. As the Ideas Lab progresses, participants will dynamically develop and hone novel ideas about how the identified challenges may be addressed, and then use these ideas and approaches to develop research projects, which should contain genuinely innovative and potentially risk-taking investigations. The Ideas Lab will include inputs from a variety of sources and will aim to

develop collaborative research projects. Following the Ideas Lab, proposals may be submitted by teams selected to submit a full proposal. Those selected teams will receive further instructions.

The nature of the Ideas Lab requires a high degree of trust between participants in order to make the required breakthroughs in scientific thinking. This trust extends to allowing the free and frank exchange of scientific ideas, some being in the very early stages of development. The aim of the Ideas Lab is not to discuss ideas that are already well-developed but not yet published. Rather, the goal is to bring individuals from different disciplines together to interact and engage in free thinking on first principles, to learn from one another and create an integrated vision for future research projects. It is expected that the sharing of these ideas would be encouraged within the Ideas Lab but their confidentiality would be respected outside the Ideas Lab.

The Ideas Lab will be led by Director(s) whose role will be to assist in defining the topics and help facilitate discussions at the event. The Director(s) will be joined by a small number of mentors. The mentors will be selected by NSF based on their intellectual standing, their impartiality and objectivity, and their broad understanding of, and enthusiasm for, the subject area. The Director(s) and mentors will take full part in the Ideas Lab, but will not be eligible to receive research funding under this collaborative activity. They will therefore act as impartial peer reviewers in the process, providing a function analogous to that of an NSF review panel.

The process can be broken down into several stages:

- Defining the scope of the challenges
- Evolving common languages and terminologies amongst people from a diverse range of backgrounds and disciplines
- Sharing perspectives and understanding of the scientific challenges, as well as the diverse expertise brought by the participants to the Ideas Lab
- Taking part in break-out sessions focused on the challenges, using creative thinking techniques
- Capturing the outputs in the form of highly innovative research projects
- Using "real-time" peer review to develop projects at the Ideas Lab

The Ideas Lab will be an intensive event. For the well-being of participants, the venue offers opportunities for relaxation, and the timetable will include networking and other activities as a break from the detailed technical discussions.

#### **Who Should Apply to Participate?**

Having the right mix of participants influences the success or failure of such an activity. Applications are encouraged from individuals representing diverse research areas across a range of disciplines. Contributions to this challenge could be made by researchers working in a variety of disciplines or research areas such as atomic and molecular physics, astronomy, mathematics and statistics, engineering, etc. However, we are not defining the disciplines that should be represented at this Ideas Lab; rather we are asking potential participants to indicate how their expertise can address the challenge of developing and operating a practical fully-connected quantum computer.

The ability to develop and pursue a new approach will also be crucial. Expertise is required from a very broad range of disciplines, and applicants should not feel limited by conventional perceptions: the Ideas Lab approach is about bringing people together who would not normally interact. We actively encourage people to apply who are experts in their own research areas but have not yet applied it to this challenge.

#### **Location and Date**

This Ideas Lab will take place at the *Santa Fe Institute* in Santa Fe, NM, from **August 28 to September 1, 2017**. Further details of this venue are available at <http://www.santafe.edu>. The environment will encourage free and open-minded thinking, vital for the purposes of this event. Additional information about the venue and meeting logistics will be provided to the selected participants. It should be noted that travel to the Ideas Lab, accommodation, refreshments, breakfast, lunch and dinner costs will be covered by the NSF. However, all incidental costs incurred while at the event will be borne by the participant.

#### **Applications for this Activity**

In brief, any individual interested in participating in the Ideas Lab should respond to this solicitation by submitting a preliminary proposal application. Participation in the Ideas Lab is by invitation only from the pool of applicants who submitted a preliminary proposal.

Submission of the preliminary proposal will be considered an indication of availability to attend and participate through the full course of the five-day Ideas Lab, which will be held at the Santa Fe Institute, in Santa Fe, NM, from August 28 to September 1, 2017.

Participants will be selected on the basis of the interests, expertise, and other characteristics described in their submitted preliminary proposals.

Following the Ideas Lab, teams may be selected to submit full proposals to the NSF by the November 30, 2017 deadline. These full proposals must reflect the outline developed at the meeting.

### **III. AWARD INFORMATION**

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**Anticipated Type of Award:** Continuing Grant or Standard Grant or Cooperative Agreement

**Estimated Number of Awards:** 1 to 2

Up to 2 awards are expected in FY 2018 depending upon availability of funds and the type, scale, and variety of project ideas developed at the Ideas Lab.

**Anticipated Funding Amount:** \$5,000,000 to \$15,000,000

Up to \$3,000,000 will be available for US researchers in FY 2018 for successful proposals through the Ideas Lab, pending availability of funds and compelling proposals.

Estimated program budget, number of awards and average award size/duration are subject to availability of funds in in FY 2018 and later years.

## IV. ELIGIBILITY INFORMATION

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### Who May Submit Proposals:

The categories of proposers eligible to submit proposals to the National Science Foundation are identified in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG), Chapter I.E.

### Who May Serve as PI:

There are no restrictions or limits.

### Limit on Number of Proposals per Organization:

There are no restrictions or limits.

### Limit on Number of Proposals per PI or Co-PI: 1

## V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

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### A. Proposal Preparation Instructions

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**Preliminary Proposals (required):** Preliminary proposals are required and must be submitted via the NSF FastLane system, even if full proposals will be submitted via Grants.gov.

Submission of Preliminary Proposals is required for participation in the Ideas Lab. Please note, Preliminary Proposal must come from one individual and cannot include Co-PIs or collaborators. Participants in the Idea Lab will be selected on the basis of information submitted in the preliminary proposal. The applications should be submitted as a preliminary proposal in the NSF FastLane system ONLY, not through Grants.gov. Standard NSF formatting guidelines apply. See the NSF PAPPG for general guidance and the PAPPG Chapter II.E.5.b for specific Ideas Lab requirements.

As described in the PAPPG Chapter II.E.5, the Project Description section of the preliminary proposal is limited to two pages and should conform to the following guidelines:

Page One:

- Provide a brief summary of your professional background (no more than one half page). Please note that if you are selected as a participant, information provided in answer to this question will be made available to the other participants to facilitate networking at the Ideas Lab meeting.
- What expertise do you bring that is relevant to the development and operation of a practical fully-connected quantum computer? (no more than half a page).

Page Two:

Please spend some time considering your answers to the following questions. Your responses (no more than 150 words each) should demonstrate that you have suitable skills and aptitude to participate in the Ideas Lab (unrelated to your research track record).

- What is your personal experience with working in teams?
- How would you describe your ability to explain your research to non-experts?
- The Ideas Lab environment is especially suited to individuals who are willing to step outside their particular area of interest or expertise, who are positively driven, who enjoy creative activity, who can think innovatively and who can settle in easily in the company of strangers. Please describe an experience you have had in a comparable environment.
- What would you personally and professionally gain from participating in this Ideas Lab?

**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](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](mailto: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: ([https://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=grantsgovguide](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) 292-7827 or by e-mail from [nsfpubs@nsf.gov](mailto: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.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.

Full proposals based on project ideas developed through interactions at the Ideas lab should conform to the project outline developed at the conclusion of the meeting. If substantive changes are contemplated, an NSF Program Director should be contacted for guidance.

All full proposals should include a single copy document that contains a list of collaborators and other affiliations information for the investigators involved in the project. See below for required format.

### 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.

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## B. Budgetary Information

### Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

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## C. Due Dates

- **Preliminary Proposal Due Date(s) (required)** (due by 5 p.m. submitter's local time):

June 19, 2017

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

November 30, 2017

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## 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](mailto: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](mailto: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

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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/](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 *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

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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

This activity, particularly the Ideas Lab approach, is designed to foster the development and implementation of creative and innovative project ideas that have the potential to transform research paradigms and/or solve intractable problems. We anticipate that awards made through this solicitation will be high-risk/high-impact, as they represent new and unproven ideas, approaches and/or technologies. Projects that involve the application of novel, collaborative, or interdisciplinary approaches will therefore receive priority during the consideration process. In addition, full proposals derived from the Ideas Lab will be evaluated to determine whether the scientific themes/objectives in the proposal are congruent with the ideas presented at the Ideas Lab, and whether any significant changes in project scope or resources from those presented at the Ideas Lab have been justified.

Full proposals submitted in response to this program solicitation will be reviewed internally by the cognizant NSF Program Officers, the Ideas Lab mentors, and other external reviewers, as appropriate.

## B. Review and Selection Process

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Proposals submitted in response to this program solicitation will be reviewed by Ad hoc Review and/or Panel Review, Internal NSF Review, or Ideas Lab Mentors.

The Ideas Lab review and selection process is outlined in the PAPPG Chapter II.E.5.

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.

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## VII. AWARD ADMINISTRATION INFORMATION

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### A. Notification of the Award

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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

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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](https://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](mailto: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=papppg](https://www.nsf.gov/publications/pub_summ.jsp?ods_key=papppg).

### C. Reporting Requirements

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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 Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at [https://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=aag](https://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag).

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## VIII. AGENCY CONTACTS

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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:

- Bogdan Mihaila, telephone: (703) 292-8235, email: [bmihaila@nsf.gov](mailto:bmihaila@nsf.gov)
- Almadena Y. Chtchelkanova, telephone: (703) 292-8910, email: [achtchel@nsf.gov](mailto:achtchel@nsf.gov)
- Akbar Sayee, telephone: (703) 292-4753, email: [asayeed@nsf.gov](mailto:asayeed@nsf.gov)

For questions related to the use of FastLane, contact:

- FastLane Help Desk, telephone: 1-800-673-6188; e-mail: [fastlane@nsf.gov](mailto:fastlane@nsf.gov).
- Ramona Winkelbauer, telephone: (703) 292-7390, email: [rwinkelb@nsf.gov](mailto:rwinkelb@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](mailto:support@grants.gov).

## IX. OTHER INFORMATION

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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

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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 <https://www.nsf.gov>

- **Location:** 2415 Eisenhower Avenue, Alexandria, VA 22314
- **For General Information** (703) 292-5111

(NSF Information Center):

- **TDD (for the hearing-impaired):** (703) 292-5090

- **To Order Publications or Forms:**

Send an e-mail to: [nsfpubs@nsf.gov](mailto:nsfpubs@nsf.gov)

or telephone: (703) 292-7827

- **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 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  
Alexandria, VA 22314

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