

# Exploiting Parallelism and Scalability (XPS)

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## PROGRAM SOLICITATION NSF 13-507



National Science Foundation

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

Office of Cyberinfrastructure

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

February 20, 2013

### IMPORTANT INFORMATION AND REVISION NOTES

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A revised version of the **NSF Proposal & Award Policies & Procedures Guide** (PAPPG), [NSF 13-1](#), was issued on October 4, 2012 and is effective for proposals submitted, or due, on or after January 14, 2013. Please be advised that the guidelines contained in [NSF 13-1](#) apply to proposals submitted in response to this funding opportunity. Proposers who opt to submit prior to January 14, 2013, must also follow the guidelines contained in [NSF 13-1](#).

Please be aware that significant changes have been made to the PAPPG to implement revised merit review criteria based on the National Science Board (NSB) report, [National Science Foundation's Merit Review Criteria: Review and Revisions](#). While the two merit review criteria remain unchanged (Intellectual Merit and Broader Impacts), guidance has been provided to clarify and improve the function of the criteria. Changes will affect the project summary and project description sections of proposals. Annual and final reports also will be affected.

A by-chapter summary of this and other significant changes is provided at the beginning of both the [Grant Proposal Guide](#) and the [Award & Administration Guide](#).

*Please note that this program solicitation may contain supplemental proposal preparation guidance and/or guidance that deviates from the guidelines established in the [Grant Proposal Guide](#).*

### SUMMARY OF PROGRAM REQUIREMENTS

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#### General Information

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Program Title:

Exploiting Parallelism and Scalability (XPS)

Synopsis of Program:

Computing systems have undergone a fundamental transformation from the single-processor devices of the turn of the century to today's ubiquitous and networked devices and warehouse-scale computing via the cloud. Parallelism has become ubiquitous at many levels. The proliferation of multi- and many-core processors, ever-increasing numbers of interconnected high performance and data intensive edge devices, and the data centers servicing them, is enabling a new set of global applications with large economic and social impact. At the same time, semiconductor technology is facing fundamental physical limits and single processor performance has plateaued. This means that the ability to achieve predictable performance improvements through improved processor technologies has ended.

The Exploiting Parallelism and Scalability (XPS) program aims to support groundbreaking research leading to a new era of parallel computing. XPS seeks research re-evaluating, and possibly re-designing, the traditional computer hardware and software stack for today's heterogeneous parallel and distributed systems and exploring new holistic approaches to parallelism and scalability. Achieving the needed breakthroughs will require a collaborative effort among researchers representing all areas-- from the application layer down to the micro-architecture-- and will be built on new concepts and new foundational principles. New approaches to achieve scalable performance and usability need new abstract models and algorithms, programming models and languages, hardware architectures, compilers, operating systems and run-time systems, and exploit domain and application-specific knowledge. Research should also focus on energy- and communication-efficiency and on enabling the division of effort between edge devices and clouds.

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.

- John H. Reppy, CISE/CCF, telephone: (703) 292-7849, email: [jreppy@nsf.gov](mailto:jreppy@nsf.gov)
- Balasubramanian Kalyanasundaram, CISE/CCF, telephone: (703) 292-8910, email: [bkalyana@nsf.gov](mailto:bkalyana@nsf.gov)
- Daniel Katz, OCI, telephone: (703) 292-2254, email: [dkatz@nsf.gov](mailto:dkatz@nsf.gov)
- Geoffrey Brown, CISE/CNS, telephone: (703) 292-8950, email: [gebrown@nsf.gov](mailto:gebrown@nsf.gov)
- Hong Jiang, CISE/CCF, telephone: (703) 292-8910, email: [hjiang@nsf.gov](mailto:hjiang@nsf.gov)

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

- 47.070 --- Computer and Information Science and Engineering
- 47.080 --- Office of Cyberinfrastructure

## Award Information

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Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 20

Approximately 20 awards of up to \$750,000 for periods up to 4 years are anticipated, subject to availability of funds.

Anticipated Funding Amount: \$15,000,000

\$15,000,000 is anticipated to be awarded, subject to availability of funds.

## Eligibility Information

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Organization Limit:

The categories of proposers eligible to submit proposals to the National Science Foundation are identified in the Grant Proposal Guide, Chapter I, Section E.

PI Limit:

Each proposal is required to have two or more PIs providing different and distinct expertise relevant to the program's focus areas. More details are available in Section V.A. Proposal Preparation Instructions.

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI: 2

An investigator may participate as PI, co-PI, or senior personnel in no more than two proposals submitted in response to this solicitation.

In the event that an individual exceeds this limit, proposals will be accepted based on earliest date and time of proposal submission. That is, the first two proposals received will be accepted and the remainder will be returned without review. No exceptions will be made.

Proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by NSF.

## Proposal Preparation and Submission Instructions

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### A. Proposal Preparation Instructions

- Letters of Intent: Not Applicable
- Preliminary Proposal Submission: Not Applicable
- Full Proposals:
  - Full Proposals submitted via FastLane: NSF Proposal and Award Policies and Procedures Guide, Part I: Grant Proposal Guide (GPG) Guidelines apply. The complete text of the GPG is available electronically on the NSF website at: [http://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=gpg](http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg).
  - 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](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: Other budgetary limitations apply. Please see the full text of this solicitation for further information.

## C. Due Dates

- Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):  
February 20, 2013

## Proposal Review Information Criteria

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Merit Review Criteria: National Science Board approved criteria apply.

## 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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Computing systems have undergone a fundamental transformation from the relatively isolated single-processor devices of the turn of the century to the ubiquitous and networked devices of today and to warehouse-scale computing via the cloud. Parallelism has become ubiquitous at many levels: from the underlying circuits, to pipelining and instruction level parallelism on cores, multiple cores on a chip as well as in a machine, multiple machines on a rack, many racks in a data center, to the globally shared infrastructure of the Internet. The proliferation of multi- and many-core processors, ever-increasing numbers of interconnected high performance and data intensive edge devices, and the data centers servicing them, is enabling a new set of global applications with large economic and social impact. These applications involve people and massive amounts of data: personalized healthcare, human network analytics, disaster preparation and response, and collaborative, computation-driven scientific research.

At the same time, a main driver of continued performance improvement is ending: semiconductor technology is facing fundamental physical limits and single processor performance has plateaued. Two recent reports, "21<sup>st</sup> Century Computer Architecture" commissioned by the Computing Community Consortium (<http://cra.org/cccdocs/init/21stcenturyarchitecturewhitepaper.pdf>) and the 2011 NRC report on "The Future of Computing Performance: Game Over or Next Level?" ([http://www.nap.edu/catalog.php?record\\_id=12980](http://www.nap.edu/catalog.php?record_id=12980)) highlight this development and its impact on science, the economy, and society. The reports pose the question of how to enable the computational systems that will support emerging applications without the benefit of near-perfect performance scaling from hardware improvements. NSF's *Advanced Computing Infrastructure: Vision and Strategic Plan* (<http://www.nsf.gov/pubs/2012/nsf12051/nsf12051.pdf>) published in February 2012 describes strategies that address this challenge for NSF and the research community. The XPS program is part of the larger NSF CIF21 framework.

Our ability to achieve predictable performance improvements through traditional processor technologies has ended. To avoid a crisis and to continue improving performance, we need a new era of parallel computing driven by novel, groundbreaking research in all areas impacting parallel performance and scalability. Achieving the needed breakthroughs will require a collaborative effort among researchers representing all areas from the application layer down to the micro-architecture, and will be built on new concepts and new foundational principles. In this solicitation, we look for groundbreaking research arising from collaborations that involve researchers providing different and distinct expertise relevant to the program's focus areas, which together re-examine the traditional computer hardware and software stack. For example, collaborations combining a deep understanding in parallel programming with

expertise in software tools; experience in heterogeneous parallel architectures with algorithm design; knowledge in an application domain with expertise in energy-efficient memory hierarchies; hardware design expertise with human factors expertise; experience in runtime platforms and virtualization tools with knowledge in reliable and distributed computing.

## II. PROGRAM DESCRIPTION

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This program seeks transformative proposals on new and visionary approaches that re-examine the traditional computer hardware and software stack for today's heterogeneous parallel systems and explore new cross-layer approaches. Research should re-evaluate, and possibly re-design, the traditional computer hardware and software stack for today's heterogeneous parallel systems and explore new holistic approaches to parallelism and cross-layer design. New approaches should encompass both software and hardware to achieve scalable performance and usability through new abstract models and algorithms, programming models and languages, hardware architectures, compilers and runtime systems. Research should focus on scalable performance, on energy- and communication-efficiency, and on enabling the division of effort between edge devices and clouds. Programmability, reliability, security, and privacy are all of primary importance.

Proposals should address problems related to at least one of the four focus areas : (1) foundational principles, (2) cross-layer and cross-cutting approaches, (3) scalable distributed architectures, and (4) domain-specific design. All proposals must identify with a focus area (see "Proposal Preparation Instructions" for details of identifying the research focus area).

### Foundational Principles (FP)

Research on foundational principles should engender a paradigm shift in the ways in which one conceives, develops, analyzes, and uses parallel algorithms, languages, and concurrency. Foundational research should be guided by crucial design principles and constraints impacting these principles. Topics include, but are not limited to:

- New computational models that free the programmer from many low-level details of specific parallel hardware while supporting the expression of properties of a desired computation that allows maximum parallel performance. Models should be simple enough to understand and use, have solid semantic foundations, and guide algorithm design choices for diverse parallel platforms.
- Algorithms and algorithmic paradigms that simultaneously allow reasoning about parallel performance, lead to provable performance guarantees, and allow optimizing for various resources, including energy, memory hierarchy, and communication bandwidth as well as parallel work and running time.
- New programming languages and language mechanisms that support new computational models, raise the level of abstraction, and lower the barrier of entry for parallel and concurrent programming. Parallel and concurrent languages that have programmability, verifiability, and scalable performance as design goals. Of particular interest are languages that abstract away from the traditional imperative programming model found in most sequential programming languages.
- Compilers and techniques for mapping high-level parallel languages and language mechanisms to efficient low-level, platform-specific code.
- Development of interfaces to express parallelism at a higher level while being able to express and analyze locality, communication, and other parameters that affect performance and scalability.

### Cross-layer and Cross-cutting Approaches (CLCCA)

In order to fully exploit the power of current and emerging computer architectures, research is needed that re-evaluates, and possibly re-designs, the traditional computer hardware and software stack - applications, programming languages, compilers, runtime systems, virtual machine, operating systems and architecture - for today's heterogeneous parallel systems. A successful approach should be a collaboration that explores new holistic approaches to parallelism and cross-layer design. Topics include, but are not limited to:

- New abstractions, models, and software systems that expose fundamental attributes, such as energy use and communication costs, across all layers and that are portable across different platforms and architectural generations.
- New software and system architectures that are designed for exploitable locality, with parallelism and communication efficiency to minimize energy use, and using on-chip and chip-to-chip communication achieving low latency, high bandwidth, and power efficiency.
- New methods and metrics for evaluating, verifying and validating reliability, resilience, performance, and scalability of concurrent, parallel, and heterogeneous systems.
- Runtime systems to manage parallelism, memory allocation, synchronization, communication, I/O, and energy usage.
- Extracting general principles that can drive the future generation of computing architectures and tools with a focus on scalability, reliability, robustness, security and verifiability.
- Exploration of tradeoffs addressing an optimized "separation of concerns." Which problems should be handled by which layers? What information and abstractions must flow between the layers to achieve optimal performance? Which aspects of system design can be automated and what is the optimal use of costly human ingenuity?

### Scalable Distributed Architectures (SDA)

Many emerging applications require a rich environment that enables sensing and computing devices that communicate with each other and with warehouse-scale facilities via the cloud, which in turn processes and supplies information for edge devices, such as smart phones. Research is needed into the components and the programming of such highly parallel and scalable distributed architectures. Topics include, but are not limited to:

- Novel approaches that enable smart sensor design with the constraints of low energy use, tight form factors, tight time constraints and adequate computational capacity, and low cost. Exemplary approaches include using innovative communication modalities and data-specific approximate computing techniques.
- Runtime platforms and virtualization tools that allow programs to divide effort between and among portable platforms and the cloud while responding dynamically to changes in the reliability and energy efficiency of the cloud uplink. Possible questions to address include: How should computation be distributed between the nodes and cloud infrastructure? How can system architecture help preserve privacy by giving users more control over their data? Should compute engines and memory systems be co-designed?
- Research that enables conventionally-trained engineers to program warehouse-scale computers, taking advantage of the highly parallel and distributed environment and at the same time being resilient to significant amounts of component and communication failures. Such research may be based on novel hardware support, programming abstractions, new algorithms, storage systems, middleware, operating systems and/or virtualization.

## Domain-specific Design (DSD)

Research is needed on how to exploit domain and application-specific knowledge to improve programmability, reliability, and scalable parallel performance. Topics include, but are not limited to:

- Parallel domain-specific languages that provide both high-level programming models for domain experts and high performance across a range of parallel platforms, such as GPUs, SMPs, and clusters.
- Program synthesis tools that generate efficient parallel codes from high-level problem descriptions using domain-specific knowledge. Approaches might include optimizations based on mathematical and/or statistical reasoning, auto-vectorization techniques that exploit domain-specific properties, and auto-tuning techniques.
- Hardware-software co-design for domain-specific applications that pushes performance and energy efficiency while reducing cost, overhead, and inefficiencies.
- Integrated data management paradigms harnessing parallelism and concurrency, encompassing the entire data path from generation to transmission, to storage, use, security, and maintenance, to eventual archiving or destruction.
- Work that generalizes the approach of exploiting domain-specific knowledge, such as tools, frameworks, and libraries that support the development of domain-specific solutions to computational problems and are integrated with domain science.
- Novel approaches suitable for scientific application frameworks addressing domain-specific mapping of parallelism onto a variety of parallel computational models and scales.

## III. AWARD INFORMATION

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We estimate that \$15.0 million will be made available in FY 2013 to support up to 20 awards.

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

## IV. ELIGIBILITY INFORMATION

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Organization Limit:

The categories of proposers eligible to submit proposals to the National Science Foundation are identified in the Grant Proposal Guide, Chapter I, Section E.

PI Limit:

Each proposal is required to have two or more PIs providing different and distinct expertise relevant to the program's focus areas. More details are available in Section V.A. Proposal Preparation Instructions.

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI: 2

An investigator may participate as PI, co-PI, or senior personnel in no more than two proposals submitted in response to this solicitation.

In the event that an individual exceeds this limit, proposals will be accepted based on earliest date and time of proposal submission. That is, the first two proposals received will be accepted and the remainder will be returned without review. No exceptions will be made.

Proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by NSF.

## V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

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### A. Proposal Preparation Instructions

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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 Grant Proposal Guide (GPG). The complete text of the GPG is available electronically on the NSF website at: [http://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=gpg](http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg). Paper copies of the GPG 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: ([http://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=grantsgovguide](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](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. Chapter II, Section D.4 of the Grant Proposal Guide provides additional information on collaborative proposals.

**Important Proposal Preparation Information:** FastLane will check for required sections of the proposal, in accordance with *Grant Proposal Guide* (GPG) instructions described in Chapter II.C.2. The GPG requires submission of: Project Summary; Project Description; References Cited; Biographical Sketch(es); Budget; Budget Justification; Current and Pending Support; Facilities, Equipment & Other Resources; Data Management Plan; and Postdoctoral Mentoring Plan, if applicable. If a required section is missing, FastLane will not accept the proposal.

Please note that the proposal preparation instructions provided in this program solicitation may deviate from the GPG instructions. If the solicitation instructions do not require a GPG-required section to be included in the proposal, insert text or upload a document in that section of the proposal that states, "Not Applicable for this Program Solicitation." Doing so will enable FastLane to accept your proposal.

Proposal titles must indicate the XPS program, followed by a colon, then the focus area followed by a colon, followed by the title of the project. For example, a proposal in the Foundational Principals focus area would be XPS: FP: Title. If multiple focus areas are involved, the most relevant one to the research being proposed should be listed.

Achieving the breakthroughs the XPS program seeks will require a collaborative effort among researchers representing all areas from the application layer down to the micro-architecture. Each proposal is required to have two or more PIs providing different and distinct expertise relevant to the program's focus areas. For example, collaborations combining a deep understanding in parallel programming with expertise in software tools; experience in heterogeneous parallel architectures with algorithm design; knowledge in an application domain with expertise in energy-efficient memory hierarchies; hardware design expertise with human factors expertise; experience in runtime platforms and virtualization tools with knowledge in reliable and distributed computing.

Proposals are required to have a collaboration plan as a separate supplementary document (limited to 2 pages). This document must describe the background and different expertise of the PIs, how this relates to the proposed work, and how the PIs plan to collaborate.

## B. Budgetary Information

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**Cost Sharing:** Inclusion of voluntary committed cost sharing is prohibited

**Other Budgetary Limitations:** Proposal budgets must not exceed \$750,000.

**Budget Preparation Instructions:** PI meetings will be held in 2014 and 2016 at locations in the continental United States. The proposal budget should include funds for travel for 2 PIs to each of these meetings.

## C. Due Dates

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- Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):  
February 20, 2013

## D. FastLane/Grants.gov Requirements

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- For Proposals Submitted Via FastLane:

Detailed technical instructions regarding the technical aspects of preparation and submission via FastLane are 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.

**Submission of Electronically Signed Cover Sheets.** The Authorized Organizational Representative (AOR) must electronically sign the proposal Cover Sheet to submit the required proposal certifications (see Chapter II, Section C of the Grant Proposal Guide for a listing of the certifications). The AOR must provide the required electronic certifications within five working days following the electronic submission of the proposal. Further instructions regarding this process are available on the FastLane Website at: <https://www.fastlane.nsf.gov/fastlane.jsp>.

- 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://www07.grants.gov/applicants/app\\_help\\_reso.jsp](http://www07.grants.gov/applicants/app_help_reso.jsp). In addition, the NSF Grants.gov Application Guide provides additional technical guidance regarding 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.

## 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 the GPG as [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/meritreview/>.

Proposers should also be aware of core strategies that are essential to the fulfillment of NSF's mission, as articulated in [Empowering the Nation Through Discovery and Innovation: NSF Strategic Plan for Fiscal Years \(FY\) 2011-2016](#). 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 core strategies 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 provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students, and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the variety of learning perspectives.

Another core strategy in support of NSF's mission is broadening 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. (GPG 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 GPG 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.

## 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.

Reviewers will be asked to formulate a recommendation to either support or decline each proposal. 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 is striving to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. The time interval begins on the deadline or target date, or receipt date, whichever is later. The interval ends when the Division Director accepts the Program Officer's recommendation.

A summary rating and accompanying narrative will be completed and submitted by each reviewer. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers, 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.

In all cases, 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 and 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.

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

## 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 at least 90 days prior to the end of the current budget period. (Some programs or awards require submission of more frequent project reports). Within 90 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 [http://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=aag](http://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag).

## 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:

- John H. Reppy, CISE/CCF, telephone: (703) 292-7849, email: [jreppy@nsf.gov](mailto:jreppy@nsf.gov)
- Balasubramanian Kalyanasundaram, CISE/CCF, telephone: (703) 292-8910, email: [bkalyana@nsf.gov](mailto:bkalyana@nsf.gov)
- Daniel Katz, OCI, telephone: (703) 292-2254, email: [dkatz@nsf.gov](mailto:dkatz@nsf.gov)
- Geoffrey Brown, CISE/CNS, telephone: (703) 292-8950, email: [gebrown@nsf.gov](mailto:gebrown@nsf.gov)
- Hong Jiang, CISE/CCF, telephone: (703) 292-8910, email: [hjiang@nsf.gov](mailto:hjiang@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).

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, National Science Foundation Update is a free e-mail subscription service 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 Regional Grants Conferences. Subscribers are informed through e-mail when new publications are issued that match their identified interests. Users can subscribe to this service by clicking the "Get NSF Updates by Email" link on the [NSF web site](#).

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding

opportunities may be accessed via this new 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* provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See Grant Proposal Guide Chapter II, Section D.2 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>

- Location: 4201 Wilson Blvd. Arlington, VA 22230
- For General Information (NSF Information Center): (703) 292-5111
- TDD (for the hearing-impaired): (703) 292-5090
- To Order Publications or Forms:
  - Send an e-mail to: [nspubs@nsf.gov](mailto:nspubs@nsf.gov)
  - or telephone: (703) 292-7827
- To Locate NSF Employees: (703) 292-5111

## PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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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  
Division of Administrative Services  
National Science Foundation  
Arlington, VA 22230

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The National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230, USA  
Tel: (703) 292-5111, FIRS: (800) 877-8339 | TDD: (800) 281-8749

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