# Computer and Network Systems (CNS): Core Programs

## PROGRAM SOLICITATION
NSF 16-579

## REPLACES DOCUMENT(S):
NSF 15-572

**National Science Foundation**

Directorate for Computer & Information Science & Engineering
Division of Computer and Network Systems

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

October 12, 2016 - October 19, 2016

October 12 - October 19, Annually Thereafter

MEDIUM Projects

October 12, 2016 - October 19, 2016

October 12 - October 19, Annually Thereafter

LARGE Projects

November 02, 2016 - November 16, 2016

November 2 - November 16, Annually Thereafter

SMALL Projects

## IMPORTANT INFORMATION AND REVISION NOTES

This is a revision of NSF 15-572, the solicitation for the CISE/CNS Core Programs. The revisions include: Under Additional Solicitation Specific Review Criteria, reviewers are now asked to provide specific evaluation of whether key personnel, and especially lead PIs, have allocated adequate time for both their individual technical contributions and the leadership of collaborative activities necessary to realize the synergistic effects of larger-scale research.

The following recent revisions to the *Grant Proposal Guide* (GPG) will be closely observed for all submissions to this solicitation:

- GPG Chapter II.C.2.d.i requires that, "The Project Description must contain, as a separate section within the narrative, a section labeled 'Broader Impacts'."
- GPG Chapter II.C.2.f clarifies the requirements for Biographical Sketch(es).
- GPG Chapter II.C.2.h revises requirements for reporting Current and Pending Support.
- GPG Chapter II.C.2.j Special Information and Supplementary Documentation, specifies the proper scope for letters of collaboration.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 16-1), which is effective for proposals submitted, or due, on or after January 25, 2016.

## SUMMARY OF PROGRAM REQUIREMENTS

### General Information

**Program Title:**

Computer and Network Systems (CNS): Core Programs

**Synopsis of Program:**

CISE's Division of Computer and Network Systems (CNS) supports research and education projects that develop new knowledge in two core programs:

- Computer Systems Research (CSR) program; and
- Networking Technology and Systems (NeTS) program.

Proposers are invited to submit proposals in three project classes, which are defined as follows:

- Small Projects - up to $500,000 total budget with durations up to three years;

- Medium Projects - $500,001 to $1,200,000 total budget with durations up to four years; and
- Large Projects - $1,200,001 to $3,000,000 total budget with durations up to five years.

A more complete description of the three project classes can be found in section *II. Program Description* of this document.

**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.*

- Jack Brassil, NeTS Program Director, 1175, telephone: (703) 292-8950, email: jbrassil@nsf.gov
- Darleen L. Fisher, NeTS Program Director, 1175, telephone: (703) 292-8950, email: dlfisher@nsf.gov
- Wenjing Lou, NeTS Program Director, 1175, telephone: (703) 292-8950, email: wlou@nsf.gov
- Mimi McClure, CSR Associate Program Director, 1175, telephone: (703) 292-8950, email: mmcclure@nsf.gov
- Thyagarajan Nandagopal, NeTS Program Director, 1175, telephone: (703) 292-8950, email: tnandago@nsf.gov
- Gurdip Singh, CSR Program Director, 1175, telephone: (703) 292-8950, email: gsingh@nsf.gov
- Yan Solihin, CSR Program Director, 1175, telephone: (703) 292-7939, email: ysolihin@nsf.gov

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

- 47.070 --- Computer and Information Science and Engineering

## Award Information

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

**Estimated Number of Awards:** 100 to 150

awards will be made each year.

**Anticipated Funding Amount:** $60,000,000

per year, dependent upon the availability of funds.

## Eligibility Information

**Who May Submit Proposals:**

Proposals may only be submitted by the following:

- Universities and Colleges - Universities and two- and four-year colleges (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.
- Non-profit, non-academic organizations: Independent museums, observatories, research labs, professional societies and similar organizations in the U.S. associated with educational or research activities.

**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:** 2

In any contiguous October through November period, an individual may participate as PI, Co-PI or Senior Personnel in **no more than two Small, Medium, or Large** proposals submitted in response to the *coordinated solicitation* (where *coordinated solicitation* is defined to include the *Computer and Network Systems (CNS): Core Programs*, *Computing and Communication Foundations (CCF): Core Programs*, and the *Information and Intelligent Systems (IIS): Core Programs solicitations)*. For example, between October 2016 and November 2016, an individual may participate as PI, co-PI or Senior Personnel in one proposal submitted to a core program in CCF and in a second proposal submitted to a core program in CNS, or an individual may participate as PI, co-PI or Senior Personnel in two proposals submitted to an IIS core program, etc.

**These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently**. In the event that an individual exceeds this limit, proposals received within the limit will be accepted based on earliest date and time of proposal submission (i.e., the first two proposals received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

The limit on the number of proposals per PI, co-PI or Senior Personnel applies only to the *coordinated solicitation*.

## Proposal Preparation and Submission Instructions

**A. Proposal Preparation Instructions**

     **Letters of Intent:** Not required

- **Preliminary Proposal Submission:** Not required

- **Full Proposals:**

  - Full Proposals submitted via 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.
  - Full Proposals submitted via Grants.gov: NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov Guidelines apply (Note: The NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide)

**B. Budgetary Information**

- **Cost Sharing Requirements:**

  Inclusion of voluntary committed cost sharing is prohibited.

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

  Not Applicable

- **Other Budgetary Limitations:**

  Not Applicable

**C. Due Dates**

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

  October 12, 2016 - October 19, 2016

  October 12 - October 19, Annually Thereafter

      MEDIUM Projects

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      SMALL Projects

## Proposal Review Information Criteria

**Merit Review Criteria:**

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

## Award Administration Information

**Award Conditions:**

Standard NSF award conditions apply.

**Reporting Requirements:**

Standard NSF reporting requirements apply.

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# I. INTRODUCTION

The Division of Computer and Network Systems (CNS) supports research and education activities that invent new computing and networking technologies and that explore new ways to make use of existing technologies. The Division seeks to develop a better understanding of the fundamental properties of computer and network systems and to create better abstractions and tools for designing, building, analyzing, and measuring future systems.

# II. PROGRAM DESCRIPTION

CNS supports two core programs as described below. In addition, CNS invites **proposals that bridge the research areas of CSR and NeTS.**

**Computer Systems Research (CSR)**

Computer systems support a broad range of applications and technologies that seamlessly integrate with human users. While many key building blocks of computer systems are today commercial technologies, the challenge ahead is to envision new technologies, as well as to combine existing technologies, software, and sensing systems into the computer systems of the future that will span wearable computing, "smart dust," the Internet of Things (IoT), "Smart Cities," intelligent transportation systems, personalized healthcare, and beyond. Such computer systems will require new, innovative, and visionary approaches to hardware, wired and wireless communications, consideration of human-computer interactions, and new programming languages and compilers that are limited only by the imagination. They will need to be reliable in the presence of unreliable components, adaptive to changing environments, capable of supporting high-throughput applications and large-scale data storage and processing, and able to meet performance and energy objectives for applications ranging from very low-power embedded systems to large high-performance computing systems. Furthermore, computer systems of the future will need to provide mechanisms for ensuring security and privacy.

The Computer Systems Research (CSR) program supports transformative scientific and engineering research leading to the development of the next generation of highly performant, heterogeneous, power-efficient, environmentally sustainable, and secure computer systems. The scope of the program includes embedded and multicore systems and accelerators; mobile and extensible distributed systems; cloud and data-intensive processing systems; and memory, storage, and file systems. The program seeks innovative research proposals that will advance the reliability, performance, power, security and privacy, scalability, and sustainability of computer systems.

CSR proposals should address problems that are appropriate to the **CSR Core Area**, to one of the current highlighted areas, or to the bridging area of networked systems. Note that proposals that address problems in the CSR highlighted areas **are not targeted for special handling or funding** -- they simply represent emerging areas or areas of current national interest.

In addition, as noted above, **CNS invites proposals that bridge the research areas of CSR and NeTS**. Some of the topics specified below in the CSR core program description, along with others, are in the realm of "networked systems," requiring innovations and expertise in both networking and computer systems. CNS welcomes proposals on these topics, which cross the CSR and NeTS core programs -- and PIs are encouraged to specify proposal titles that begin with "CSR: NeTS:" (see the Proposal Preparation Instructions for details). These proposals will be considered for co-review by the two CNS core programs as appropriate.

CSR proposals are strongly encouraged to include validation plans that describe mechanisms to assess success of the proposed research efforts.

**Validation plan:** Proposals that choose to validate their hypothesis such as through simulation, emulation or testbed experiments must adequately describe mechanisms to assess success of the proposed research efforts.

**CSR Core Area**

The CSR program supports transformative research in computing systems ranging from large-scale systems of tiny sensors and embedded computers to multi-core architectures and operating systems, to mobile and sensor systems, and to warehouse-scale cloud back-end systems and beyond. The essence of the CSR vision is the creation of future environments in which large-scale, complex, and heterogeneous systems seamlessly integrate so that the whole is greater than the sum of the individual parts. These future environments include hardware, software, sensing, and the integration of external factors, such as users and physical environments. In addition, we envision systems that provide high degrees of availability, responsiveness, fault-tolerance, and security, either on demand or by design. Finally, research on novel computer systems that push the limits on system properties including speed, storage and data capacity, power consumption, and real-time requirements is encouraged.

Future computer systems are envisioned that are integrated into everyday activities. These systems include remote, high-performance or embedded devices sensing locally and/or remotely across the surrounding environment, and acting on behalf of

individuals and even entire societies. We expect significant systems challenges across an abundance of computing systems, their heterogeneity, and the need to integrate peripheral and smaller with larger computing systems. These and other factors are expected to challenge the way we design, build and sustain computer systems.

The CSR core supports and sustains progress in the contributing disciplinary areas that underlie computing systems including: distributed systems; pervasive and high-performance computing; operating systems and middleware; design and programming models; and real-time, embedded, and hybrid systems.

**CSR Highlighted Areas**

For this solicitation, there are three CSR highlighted areas: **Embedded and Real-time Systems (ERS)**, **Edge Computing (EC)** and **Extensible Distributed Systems (EDS)**. These three areas are described below.

- **Embedded and Real-time Systems (ERS)**

  Embedded and real-time systems control devices and physical or engineered systems that range from hearing aids and pacemakers to automobiles, aircraft, chemical processing plants, electrical power grids, and global aviation infrastructure. The ERS highlight area supports research and education in scientific foundations and technology that will revolutionize the design and development of such systems.

  The goal of the ERS highlight area is to supply technologies for designing and building increasingly capable and certifiably dependable embedded and control systems, with real-time, interoperability, survivability, reliability, and security guarantees. Topics of interest include, but are not limited to: embedded systems software and programming methods; real-time services, run-time software and platforms; innovative embedded hardware technology and hardware-software co-design; scalable support for embedded sensing and real-time applications; architecture and design principles for complex embedded systems; and power and resource management and optimization.

- **Edge Computing (EC)**

The rapid growth of mobile applications and the Internet of Things have placed severe demands on cloud infrastructure, which has led to moving computing and data services towards the edge of the cloud. The resulting kinds of architectures, called "edge computing," "cloudlets," "fog computing," and "cloud of things" can reduce data transfer times, remove potential performance bottlenecks, and increase data security and enhance privacy while enabling advanced applications such as swarms of drones and robots, smart city infrastructure, and manageable and upgradable smart building and home infrastructure.

The main goal of the EC highlight area is to stimulate and promote basic research related to algorithms, design, performance, and applications of edge computing approaches and architectures. Topics of interest include, but are not limited to: situational awareness and inferential control; real-time support and quality of service (QoS); resource management; supporting the role (or lack of role) of humans in the loop; security, inclusion of personal devices; privacy enhancement; supporting edge services in resource-constrained, uncertain and unreliable environments; and novel edge services, exploiting heterogeneous wireless links and edge application-specific networking patterns given limited wireless resources. Also of interest is research that explores the joint use of shared and traditional clouds, and the effects of increasingly robust networks on edge computing.

Prospective PIs for the EC highlight area are especially encouraged to consider utilizing the two NSFFutureCloud prototypes, Chameleon and CloudLab, when formulating their research plans and submitting EC proposals. Detailed descriptions of the hardware and capabilities of each system are available on their respective websites, www.chameleoncloud.org and www.cloudlab.us. Both systems are currently open for use, with application instructions available on their websites.

- **Extensible Distributed Systems (EDS)**

With the proliferation of networked and portable computing devices that are increasingly everywhere around us (in our pockets, on our wrists and ankles, and in our cars and homes, etc.), a new generation of distributed systems is emerging. These heterogeneous systems extend traditional server and cloud systems and require close interactions with individuals who own and operate the computing devices. Users expect these systems to be robust, reliable, safe, secure, and efficient. At the same time, new applications leveraging these systems require a rich environment that enables sensing and computing along with communication among the devices and between the devices and warehouse-scale facilities via the cloud. This coupling underpins many 'smart' technologies and infrastructures of the future, such as smart buildings and informatics infrastructures, intelligent transportation systems, and smart energy distribution and consumption systems, as well as how humans interact with such technologies and infrastructures.

The goal of the EDS highlight area is to support research into the science and design of extensible distributed systems, advancing software and hardware architectures to enable us to integrate and aggregate from the smallest scale systems to systems without bounds. Topics of interest include, but are not limited to: systems models and programming abstractions that make it easy to compose components and modules to create richer applications; architectures that enable humans to better manage and maintain the applications and the systems upon which they run; tools for assessing the safety and security of applications that interact with the physical world; methods and tools for assessing uncertainty and the tradeoffs of uncertainty, time, and usability, as well as for balancing constraints such as power, energy, form factor, tight time, computational capacity, consistency, reliability, dependability, and performance; and approaches for data storage and recovery for EDS.

Both the CSR Core and the CSR highlighted areas seek proposals focused on advances in systems computing and systems programming that are particular to an application domain or a specific hardware platform as well as generic across domains and platforms.

**Networking Technology and Systems (NeTS)**

Computer and communication networks need to be available anytime and anywhere, and be accessible from any device. Networks need to evolve over time to incorporate new technologies, support new classes of applications and services, and meet new requirements and challenges; networks need to scale and adapt to unforeseen events and uncertainties across multiple dimensions, including types of applications, size and topology, mobility patterns, and heterogeneity of devices and networking technologies. Networks need to be easily controllable and manageable, resource and energy efficient, and secure and resilient to failures and attacks. The Networking Technology and Systems (NeTS) program supports transformative research on fundamental scientific and technological advances in networking as well as systems research leading to the development of future-generation, high-performance networks and future Internet architectures.

NeTS proposals should address problems that are appropriate to the **NeTS Core Area**, to one of the current **Highlighted Areas**, or to the bridging area of networked systems. Note that proposals that address problems in the NeTS highlighted areas **are not targeted for special handling or funding** -- they simply represent emerging areas or areas of current national interest.

In addition, as noted above, **CNS invites proposals that bridge the research areas of CSR and NeTS**. Some of the topics specified below in the NeTS core program description, along with others, are in the realm of "networked systems," requiring innovations and expertise in both networking and computer systems. CNS welcomes proposals on these topics, which cross the CSR and NeTS core programs -- and PIs are encouraged to specify proposal titles that begin with "CSR: NeTS:" (see the Proposal Preparation Instructions for details). These proposals will be considered for co-review by the two CNS core programs as appropriate.

NeTS proposals are strongly encouraged to include validation plans that describe mechanisms to assess success of the proposed research efforts.

**Validation plan:** Proposals that choose to validate their hypothesis such as through simulation, emulation or testbed experiments must adequately describe mechanisms to assess success of the proposed research efforts.

**NeTS Core Area**

The NeTS program seeks fundamental scientific understanding of and advances in large-scale, complex, heterogeneous communications networks, including, but not limited to, home, enterprise, data center, cloud, and Internet or Internet-scale networks, and in the wireless areas of cellular, vehicular, mesh, sensor, body area, and underwater networks. NeTS seeks novel frameworks, architectures, protocols, methodologies, and tools for the design and analysis, development, operation, and management of robust and highly dependable networks, including autonomous networks in which the need for human intervention is minimal. The program also seeks projects that enable energy-efficient operation with low control and communication overhead in wireless networks.

**NeTS Highlighted Areas**

For this solicitation, there are six highlighted areas: **Meta-Networking Research**, **Network Management**, **Optical Networking**, **Support of Next-Generation Virtualized Networks and Infrastructure**, **Wireless Network Architectures,** and **Protocols for Pervasive Wireless Networking**. These six areas are described below.

- **Meta-Networking Research**

    There is a vital need for methodologies for scientific evaluation of wired and wireless communication networks that include an understanding of network instrumentation and measurements as well as the development of rigorous scientific methods for planning and assessing networking experiments. There is also the need for approaches that advance the state of the art in the verification of correctness of network configurations.

- **Network Management**

    In this highlight area, NeTS invites innovative solutions to the problems of network management, such as diagnostics, debugging, provisioning and operations of wired and wireless networks, spanning networks in "talent-poor" or "talent-constrained" environments such as homes, small businesses, rural networks and small providers, and distributed enterprises. NSF also invites innovative solutions to problems of providing individuals with accurate user-appropriate information on network performance and impairments with a view to informing users of network behavior and potential bottlenecks. NSF is looking for novel semantics to describe and reproduce network state and evolution especially in the domains of optical, home access networks, and spectrum-agile wireless networks.

- **Optical Networking**

    NeTS invites transformational optical networking proposals that radically change the capabilities and push the limits of communication networks, as well as seamlessly integrate optical networks with future networking architectures. NeTS is especially interested in proposals that combine photonic technologies with innovation in network architectures to produce future systems, such as inexpensive optical terabit-per-second "Ethernets" capable of integrating computation, storage, data-gathering, etc. Innovative research in systems is also invited that might achieve multiple terabit-per-second performance for many users but at performance, power and cost factors superior to today's high-speed systems.

- **Support of Next-Generation Virtualized Networks and Infrastructure**

    NeTS welcomes proposals that are transformative for the technologies associated with Software Defined Networking (SDN) and Software Defined Infrastructure (SDI), and their uses. Examples of topic areas include:
    - Techniques for mapping of applications onto virtualized infrastructure such that security, performance, resilience and other properties are preserved;
    - Management of virtualized infrastructure, especially in cases where the virtualized infrastructure is dynamically changing;
    - Next-generation protocols for control of virtualized infrastructure;
    - Novel virtualization techniques for wireless networks spanning the home, access, enterprise and cellular network domains; and
    - Investigations of models, platforms, toolchains, applications, and management (e.g., field reconfigurability) of emerging programmable packet processors in support of software-defined data planes.

- **Wireless Network Architectures**

    A diverse multitude of wireless network architectures are emerging that challenge conventional wireless network and communication design principles, and are associated with novel physical-layer techniques and technological trends. Examples of novel technologies enabling new architectures include, but are not limited to:
    - Ultra-wideband millimeter-wave networks spanning frequencies above 20 gigahertz;
    - Free-space optics and visible light communications;
    - High-bandwidth, frequency-agile, airborne communication platforms (manned/unmanned), e.g., drones, high-altitude balloons/aircraft, etc.;
    - Pervasive machine-to-machine communications at large scale;
    - Highly functional, energy-harvesting, ultra-low power sensors capable of perpetual operation; and
    - Dynamic spectrum access enabled by cognitive radios.

Through this highlight area, NeTS invites proposals that address foundational aspects of wireless network architecture associated with these novel technologies, as well as proposals that incorporate these technologies into network architectures designed from scratch unconstrained by current network assumptions. NeTS welcomes proposals that are able to address key questions relating to information availability, reliability, and security, while supporting a rich set of higher layer services. Proposers should consider critical operational parameters such as throughput/latency requirements, location management, identity management, user privacy, user mobility, power/energy constraints, network heterogeneity, spectral agility, and at-scale behavior.

- **Protocols for Pervasive Wireless Networking**

Advances in hardware and computing systems are promising an innovative suite of higher-layer services that can be deployed using wireless communications as a seamless enabler. In order for this promise to be realized, novel wireless protocols need to be developed, going far beyond the current state of the art. In this highlight area, NeTS invites innovative proposals in the area of protocols for wireless communication and networking addressing one or more of the following goals:

- Reducing the typical latencies experienced in wireless networks by two-orders of magnitude;
- Supporting security and privacy of mobile users and applications above and beyond the physical layer;
- Enabling pervasive connectivity via spectrum-hopping across multiple gigahertz of wireless spectrum;
- Reducing mobile-device network interface energy consumption by more than an order of magnitude without compromising user functionality; and
- Enabling innovative higher layer services that exploit the lower-layer network functions.

For the NeTS core and highlighted areas, proposers may consider ways to interoperate with one of the three Future Internet Architecture – Next Phase (FIA-NP) projects. See http://www.nsf.gov/news/news_summ.jsp?cntn_id=131248 for information about these projects.

## PROJECT CLASSES

Proposals submitted to this solicitation must be consistent with one of three project classes defined below. Proposals will be considered for funding within their project classes.

- **SMALL Projects**

  **Small Projects, with total budgets up to $500,000 for durations of up to three years**, are well suited to one or two investigators (PI and one co-PI or other Senior Personnel) and at least one student and/or postdoc.

- **MEDIUM Projects**

  **Medium Projects, with total budgets ranging from $500,001 to $1,200,000 for durations up to four years**, are well suited to one or more investigators (PI, co-PI and/or other Senior Personnel) and several students and/or postdocs. Medium project descriptions must be comprehensive and well-integrated, and should make a convincing case that the collaborative contributions of the project team will be greater than the sum of each of their individual contributions. Rationale must be provided to explain why a budget of this size is required to carry out the proposed work. Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, **a Collaboration Plan is required for all Medium proposals with more than one investigator**. Up to 2 pages are allowed for Collaboration Plans and they must be submitted as a document under Supplementary Documentation. The length of and level of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Collaboration plans and proposed budgets should demonstrate that key personnel, and especially lead PIs, have allocated adequate time for both their individual technical contributions and the leadership of collaborative activities necessary to realize the synergistic effects of larger-scale research. **If a Medium proposal with more than one investigator does not include a Collaboration Plan, that proposal will be returned without review.** Please see *Proposal Preparation Instructions* Section V.A for additional submission guidelines.

- **LARGE Projects**

  **Large Projects, with total budgets ranging from $1,200,001 to $3,000,000 for durations of up to five years**, are well suited to two or more investigators (PI, co-PI(s), or other Senior Personnel), and a team of students and/or postdocs. Large project descriptions must be comprehensive and well-integrated, and should make a convincing case that the collaborative contributions of the project team will be greater than the sum of each of their individual contributions. Large projects will typically integrate research from various areas, either within a cluster or across clusters, or tackle ambitious goals not feasible with smaller projects. Rationale must be provided to explain why a budget of this size is required to carry out the proposed work. Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, **a Collaboration Plan is required for all Large proposals**. Up to 2 pages are allowed for Collaboration Plans and they must be submitted as a document under Supplementary Documentation. The length of and degree of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Collaboration plans and proposed budgets should demonstrate that key personnel, and especially lead PIs, have allocated adequate time for both their individual technical contributions and the leadership of collaborative activities necessary to realize the synergistic effects of larger-scale research. **If a Large proposal does not include a Collaboration Plan, that proposal will be returned without review**. Please see *Proposal Preparation Instructions* Section V.A for additional submission guidelines.

CISE investments in Small Medium and Large projects complement the Directorate's investments in the Expeditions in Computing program, where projects are funded at levels of up to $10,000,000 total for durations of up to 5 years. Additional information on the Expeditions program can be accessed at: http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503169

## BREAKTHROUGH PROPOSALS

CISE encourages proposals that promise extraordinary outcomes, with a possibly corresponding increase in uncertainty in the research plan and overall risk of success relative to traditional submissions, such as: revolutionizing disciplines or sub-disciplines, creating new fields or subfields, disrupting accepted theories and perspectives, and solving widely recognized challenging problems. In order to encourage the submission of proposals possessing one or more of these characteristics, we are offering the opportunity to submit and identify such projects as *"**Breakthrough Proposals**."*

*Breakthrough proposals* may be submitted to all CISE (CCF/CNS/IIS) core programs and may be Small, Medium, or Large. They must be submitted in accordance with the deadlines for Small, Medium, and Large proposals. Submission of a *breakthrough proposal* will count as one against the limit of two proposals per PI as described in the previous sections. The proposal preparation instructions, budgetary limits, and requirements for these proposals are identical to other proposals submitted to CISE (CCF/CNS/IIS) core programs under each of three size c*lasses with the following exceptions:*

(1) The word "breakthrough" must be listed as the first keyword in the submitted list of keywords in the Project Summary.

(2) A statement, of **up to two pages**, explaining why the proposed research can be described as "breakthrough" and how any associated uncertainty and risk will be managed, **must be submitted as a document under Supplementary Documentation.** A breakthrough proposal must include this statement in order to be considered as a breakthrough proposal. **If it does not include this statement, that proposal will be considered as a regular proposal.**

**PROPOSALS FOR CONSIDERATION BY MULTIPLE CISE PROGRAMS**

Proposals that intersect more than one CISE research program are welcome. In such cases, PIs must identify the most relevant programs in the proposal submission process (for information about submission and how to identify such proposals, see *Proposal Preparation Instructions* later in this document). CISE Program Officers will ensure that these proposals are co-reviewed as appropriate.

**IMPORTANT PROJECT CHARACTERISTICS**

The submission of far-reaching, creative research and education projects is encouraged. Funds will be used to support potentially transformative research with high-impact potential. In this way, CISE will catalyze exciting new research activities with the potential to make significant advances in the state-of-the-art.

Interdisciplinary, international and/or academic-industry collaborations that promise to result in major science or engineering advances are welcome. The directorate hopes to attract proposals from faculty at a broad range of academic institutions, including faculty at minority-serving and predominantly undergraduate institutions.

Proposals submitted should demonstrate that rich learning experiences will be provided for a diverse population of students and may propose the development of innovative curricula or educational materials that advance literacy about and expertise in areas supported by CISE.

**EMBEDDED REU SUPPLEMENTS**

The *Research Experiences for Undergraduates (REU): Sites and Supplements* solicitation (NSF 13-542) gives instructions for embedding a request for an REU Supplement in a proposal. Proposers are invited to embed a request for an REU Supplement in the typical amount **for one year only** according to normal CISE guidelines (detailed below). The amounts of the REU Supplements **do not** count against the budget limitations described in this solicitation for the Small, Medium, and Large project classes.

For single investigator projects, CISE REU supplemental funding requests should typically be for no more than two students for one year. Research teams funded through multi-investigator projects may request support for a larger number of students, commensurate with the size and nature of their projects. For example, for projects involving two principal investigators, REU supplemental funding is typically requested for about four undergraduates for one year. Requests for larger numbers of students should be accompanied by detailed justifications.

CISE expects to provide up to $8,000 per student per year through the REU supplemental support mechanism. As described in the REU program solicitation (NSF 13-542), indirect costs (F&A) are not allowed on Participant Support Costs in REU Site or REU Supplement budgets.

REU stipend support is one way to retain talented students in undergraduate education, while providing meaningful research experiences. The participation of students from groups underrepresented in computing -underrepresented minorities, women and persons with disabilities -is strongly encouraged. In addition, CISE encourages REU supplements that specifically afford US veterans an opportunity to engage in meaningful research experiences.

CISE REU supplemental funding requests must describe results of any previous such support, including students supported, papers published, etc. Other factors influencing supplemental funding decisions include the number of REU requests submitted by any one principal investigator across all of her/his CISE grants.

Investigators are encouraged to refer to the current REU program solicitation (NSF 13-542) for detailed information concerning submission requirements. Grantees with questions may also contact one of the Cognizant Program Officers listed in this solicitation.

# III. AWARD INFORMATION

Up to $60 million each year will support up to 150 awards, pending the availability of funds.

# IV. ELIGIBILITY INFORMATION

**Who May Submit Proposals:**

Proposals may only be submitted by the following:

- Universities and Colleges - Universities and two- and four-year colleges (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.
- Non-profit, non-academic organizations: Independent museums, observatories, research labs, professional societies and similar organizations in the U.S. associated with educational or research activities.

**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:** 2

In any contiguous October through November period, an individual may participate as PI, Co-PI or Senior Personnel in **no more than two Small, Medium, or Large** proposals submitted in response to the *coordinated*

*solicitation* (where *coordinated solicitation* is defined to include the *Computer and Network Systems (CNS): Core Programs*, *Computing and Communication Foundations (CCF): Core Programs*, and the *Information and Intelligent Systems (IIS): Core Programs solicitations*). For example, between October 2016 and November 2016, an individual may participate as PI, co-PI or Senior Personnel in one proposal submitted to a core program in CCF and in a second proposal submitted to a core program in CNS, or an individual may participate as PI, co-PI or Senior Personnel in two proposals submitted to an IIS core program, etc.

**These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently**. In the event that an individual exceeds this limit, proposals received within the limit will be accepted based on earliest date and time of proposal submission (i.e., the first two proposals received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

The limit on the number of proposals per PI, co-PI or Senior Personnel applies only to the *coordinated solicitation.*

**Additional Eligibility Info:**

For U.S. universities and two- and four-year colleges with overseas campuses, this solicitation restricts eligibility to research activities using the facilities, equipment, and other resources of the campus(es) located in the U.S. only. Note: this restriction is directed at institutional eligibility only; it is not intended to restrict international collaborations or research activities by subsequent awardees.

# V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

## A. Proposal Preparation Instructions

**Full Proposal Preparation Instructions**: Proposers may opt to submit proposals in response to this Program Solicitation via 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. 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. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.

- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov. The complete text of the NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

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

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via the NSF FastLane system. Chapter II, Section D.5 of the Grant Proposal Guide provides additional information on collaborative proposals.

See Chapter II.C.2 of the GPG 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 GPG instructions.

The following information SUPPLEMENTS (note that it does NOT replace) the guidelines provided in the NSF Grant Proposal Guide (GPG).

**Proposal Titles:**

Proposal titles must begin with an acronym that indicates the most relevant core program. Select an acronym from the following list:

- Computer Systems Research: CSR
- Networking Technology and Systems: NeTS

The acronym should be followed with a colon, then the project class followed by a colon, then the title of your project. For example, if you are submitting a Medium proposal to the Networking Technology and Systems core program, then your title would be **NeTS: Medium: Title**.

Proposals in the bridging area of networked systems, which cross the CSR and NeTS core programs, should begin "CSR: NeTS:", then the project class followed by a colon, then the proposal title, i.e., **CSR: NeTS: Small: Title**.

If you submit a proposal as part of a set of collaborative proposals, the title of the proposal should begin with the acronym that indicates the most relevant core program followed by a colon, then the project class followed by a colon, then "Collaborative Research" followed by a colon, and the title. For example, if you are submitting a collaborative set of proposals for a Large project to the Computer Systems Research core program, the title of each would be **CSR: Large: Collaborative Research: Title.**

Proposals from PIs in institutions that have RUI (Research in Undergraduate Institutions) eligibility should have a proposal title that begins with the acronym that indicates the most relevant program acronym, followed by a colon then the project class, followed by a colon then "RUI", followed by a colon and then the title, for example, **CSR: Small: RUI: Title.**

PIs submitting Grant Opportunities for Academic Liaison with Industry (GOALI) proposals should have a proposal title that begins with the acronym that indicates the most relevant program acronym, followed by a colon then the project class, followed by a colon then "GOALI", followed by a colon and then the title, for example, **NeTS: Small: GOALI: Title**.

Proposals that extend beyond the scope of one CISE core program or area are welcome. Proposals should be submitted in response to the solicitation for the CISE division (CCF, CNS or IIS) that includes the most relevant core program. In such cases, PIs should identify the acronym for the **most relevant** core program or area, followed by any other relevant program acronym(s) separated by colons (for example, **CSR: CHS: Medium: Title**). In this case, the proposal would be submitted to the CNS solicitation but would be considered by CNS/CSR and IIS/Cyber-Human Systems (CHS). CISE Program Officers will work with their NSF and CISE colleagues to ensure that these proposals are appropriately reviewed and considered for funding. Please see the coordinated CCF and IIS solicitations for information on other CISE core programs and the corresponding acronyms.

**Project Summary:**

The Project Summary consists of an overview, a statement on the intellectual merit of the proposed activity, and a statement on the broader impacts of the proposed activity.

Please provide between 2 and 6 sets of keywords at the end of the overview in the Project Summary. CISE personnel will use this information in implementing the merit review process. The keywords should describe the main scientific/engineering areas explored in the proposal. Keywords should be prefaced with "Keywords" followed by a colon and each keyword set should be separated by semi-colons. Keywords should be of the type used to describe research in a journal submission. They should be included at the end of the overview in the project summary and might appear, for example, as **Keywords: energy-aware computing; formal logic; computer graphics; sensor networks; information visualization; privacy. "Breakthrough proposals" should have the word "breakthrough" as the first keyword in the submitted list of keywords.**

**Project Description:**

**Length of Project Description** - Describe the research and education activities to be undertaken in **up to 15 pages for Small and Medium proposals and in up to 20 pages for Large proposals.** Describe curriculum development activities, if any, in a separate section (included in these page limits) titled "Curriculum Development Activities."

Proposers are reminded that, as specified in GPG Chapter II.C.2.d

- The Project Description must contain, as a separate section within the narrative, a section labeled "Broader Impacts." This section should include a discussion of the broader impacts of the proposed activities. **Proposals without this clearly-identifiable section will be returned without review.**

- Results from Prior NSF Support: If any PI or co-PI identified on the proposal has received NSF funding with a start date in the past five years (including any current funding and no-cost extensions), information on the award is required for each PI and co-PI, regardless of whether the support was directly related to the proposal. In cases where the PI or co-PI has received more than one award (excluding amendments), they need only report on the one award most closely related to the proposal. Funding includes not just salary support, but any funding awarded by NSF. Please refer to the GPG for details about the information that must be provided. Further requirements for this section of the proposal are in the GPG. **Note that these results from prior NSF support must be separately described under two distinct headings, "Intellectual Merit" and "Broader Impacts."**

**Supplementary Documents:**

In the Supplementary Documents Section, upload the following information where relevant:

1. *A list of Project Personnel and Partner Institutions (Note: In collaborative proposals, the lead institution should provide this information for all participants):*

   Provide current, accurate information for all personnel and institutions involved in the project. NSF staff will use this information in the merit review process to manage conflicts of interest. The list should include all PIs, Co-PIs, Senior Personnel, paid/unpaid Consultants or Collaborators, Subawardees, Postdocs, and project-level advisory committee members. This list should be numbered and include (in this order) Full name, Organization(s), and Role in the project, with each item separated by a semi-colon. Each person listed should start a new numbered line. For example:

   1. Mary Smith; XYZ University; PI
   2. John Jones; University of PQR; Senior Personnel
   3. Jane Brown; XYZ University; Postdoc
   4. Bob Adams; ABC Community College; Paid Consultant
   5. Susan White; DEF Corporation; Unpaid Collaborator
   6. Tim Green; ZZZ University; Subawardee

2. *Collaboration Plans for Medium and Large proposals (if applicable):*

   Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, **all Medium proposals that include more than one investigator and all Large proposals must include a Collaboration Plan of up to 2 pages**. The length of and degree of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Where appropriate, the Collaboration Plan might include: 1) the specific roles of the project participants in all organizations involved; 2) information on how the project will be managed across all the investigators, institutions, and/or disciplines; 3) identification of the specific coordination mechanisms that will enable cross-investigator, cross-institution, and/or cross-discipline scientific integration (e.g., yearly workshops, graduate student exchange, project meetings at conferences, use of the grid for videoconferences, software repositories, etc.), and 4) specific references to the budget line items that support collaboration and coordination mechanisms. **If a Large proposal, or a Medium proposal with more than one investigator, does not include a Collaboration Plan of up to 2 pages, that proposal will be returned without review.**

3. *Data Management Plan (required):*

   Proposals must include a supplementary document of no more than two pages labeled "Data Management Plan." This supplementary document should describe how the proposal will conform to NSF policy on the dissemination and sharing of research results.

   See Chapter II.C.2.j of the GPG for full policy implementation.

   For additional information on the Dissemination and Sharing of Research Results, see:
   http://www.nsf.gov/bfa/dias/policy/dmp.jsp.

For specific guidance for Data Management Plans submitted to the Directorate for Computer and Information Science and Engineering (CISE) see: http://www.nsf.gov/cise/cise_dmp.jsp.

4. *Breakthrough Description (if applicable):*

A statement, of **up to two pages**, explaining why the proposed research can be described as "breakthrough," and how any associated uncertainty and risk will be managed, **must be submitted as a document under Supplementary Documentation.** A breakthrough proposal must include this statement in order to be considered as a breakthrough proposal. **If a proposal does not include this statement, that proposal will be considered as a regular proposal.**

5. *Documentation of collaborative arrangements of significance to the proposal through Letters of Collaboration:*

There are two types of collaboration, one involving individuals/organizations that are included in the budget, and the other involving individuals/organizations that are not included in the budget. Collaborations that are included in the budget should be described in the Project Description. Any substantial collaboration with individuals/organizations not included in the budget should be described in the Facilities, Equipment and Other Resources section of the proposal (see GPG Chapter II.C.2.i). In either case, whether or not the collaborator is included in the budget, **a letter of collaboration from each named participating organization** *other than the submitting lead, non-lead, and/or subawardee institutions* **must be provided at the time of submission of the proposal. Such letters must explicitly state the nature of the collaboration, appear on the organization's letterhead and be signed by the appropriate organizational representative. These letters must not otherwise deviate from the restrictions and requirements set forth in the GPG, Chapter II.C.2.j.**

**Please note that letters of support may not be submitted.** Such letters do not document collaborative arrangements of significance to the project, but primarily convey a sense of enthusiasm for the project and/or highlight the qualifications of the PI or co-PI. **Reviewers will be instructed not to consider these letters of support in reviewing the merits of the proposal.**

6. *Other specialized information:*

RUI Proposals: PIs from predominantly undergraduate institutions should include a Research in Undergraduate Institutions (RUI) Impact Statement and Certification of RUI Eligibility in this section.

GOALI proposals: PIs submitting GOALI proposals should include industry-university agreement letters on intellectual property in this section.

**No other Supplementary Documents, except as permitted by the NSF** Grant Proposal Guide**, are allowed.**

**Single Copy Documents:**

*Collaborators and Other Affiliations Information: In lieu of the instructions specified in the GPG, Collaborators and Other Affiliations Information should be submitted as follows. (Note: In collaborative proposals, the lead institution should assemble and provide this information for all participants in the collaborative group):*

Provide current, accurate information for all active or recent collaborators of personnel and institutions involved in the project. NSF staff will use this information in the merit review process to manage conflicts of interest. **This list is distinct from (1) above under Supplementary Documents in that it must include all active or recent Collaborators of all personnel involved with the proposed project.** Collaborators include any individual with whom any member of the project team -- including PIs, Co-PIs, Senior Personnel, paid/unpaid Consultants or Collaborators, Subawardees, Postdocs, and project-level advisory committee members -- has collaborated on a project, book, article, report, or paper within the preceding 48 months; or co-edited a journal, compendium, or conference proceedings within the preceding 24 months. This list should be numbered and include (in this order) Full name and Organization(s), with each item separated by a semi-colon. Each person listed should start a new numbered line. The following is a sample format; other similar formats are acceptable.

1. Collaborators for Mary Smith; XYZ University; PI
    a. Helen Gupta; ABC University
    b. John Jones; University of PQR
    c. Fred Gonzales; DEF Corporation
    d. Susan White; DEF Corporation
2. Collaborators for John Jones; University of PQR; Senior Personnel
    a. Tim Green; ZZZ University
    b. Ping Chang; ZZZ University
    c. Mary Smith; XYZ University
3. Collaborators for Jane Brown; XYZ University; Postdoc
    a. Fred Gonzales; DEF Corporation
4. Collaborators for Bob Adams; ABC Community College; Paid Consultant
    a. None
5. Collaborators for Susan White; DEF Corporation; Unpaid Collaborator
    a. Mary Smith; XYZ University
    b. Harry Nguyen; Welldone Institution
6. Collaborators for Tim Green; ZZZ University; Subawardee
    a. John Jones; University of PQR

**NOTE: The list of collaborators includes all current and past projects (see above timelines) for all participants in the proposal. It is not a list of the collaborators for the given proposal; this should be provided pursuant to item (1) of Supplementary Documents above.**

## B. Budgetary Information

**Cost Sharing:**

Inclusion of voluntary committed cost sharing is prohibited.

## C. Due Dates

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

    October 12, 2016 - October 19, 2016

    October 12 - October 19, Annually Thereafter

    > MEDIUM Projects

    October 12, 2016 - October 19, 2016

    October 12 - October 19, Annually Thereafter

    > LARGE Projects

    November 02, 2016 - November 16, 2016

    November 2 - November 16, Annually Thereafter

    > SMALL Projects

## D. FastLane/Grants.gov Requirements

**For Proposals Submitted Via FastLane:**

> To prepare and submit a proposal via FastLane, see detailed technical instructions available at: https://www.fastlane.nsf.gov/a1/newstan.htm. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov. The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

**For Proposals Submitted Via Grants.gov:**

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

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

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

## VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

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

Proposers should also be aware of core strategies that are essential to the fulfillment of NSF's mission, as articulated in *Investing in Science, Engineering, and Education for the Nation's Future: NSF Strategic Plan for 2014-2018*. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

One of the strategic objectives in support of NSF's mission is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions must recruit, train, and prepare a diverse STEM workforce to advance the frontiers of science and participate in the U.S. technology-based economy. NSF's contribution to the

national innovation ecosystem is to provide cutting-edge research under the guidance of the Nation's most creative scientists and engineers. NSF also supports development of a strong science, technology, engineering, and mathematics (STEM) workforce by investing in building the knowledge that informs improvements in STEM teaching and learning.

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

## A. Merit Review Principles and Criteria

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

**1. Merit Review Principles**

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

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

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

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

**2. Merit Review Criteria**

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

The two merit review criteria are listed below. **Both** criteria are to be given **full consideration** during the review and decision-making processes; each criterion is necessary but neither, by itself, is sufficient. Therefore, proposers must fully address both criteria. (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.

**Additional Solicitation Specific Review Criteria**

For Large and relevant Medium proposals, reviewers will be asked to:

- Comment on the extent to which the project scope justifies the level of investment requested, and the degree to which the Collaboration Plan (if required) adequately demonstrates that the participating investigators will work synergistically to accomplish the project objectives.
- Comment on whether key personnel, and especially lead PIs, have allocated adequate time for both their individual technical contributions and the leadership of collaborative activities necessary to realize the synergistic effects of larger-scale research.

For Breakthrough proposals, reviewers will be asked to:

- Comment on the extent to which the project satisfies the "breakthrough qualities" as described above in Section II, including an assessment of uncertainty and risk associated with the proposed work.

## B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by

Ad hoc Review and/or Panel Review, or Asynchronous panel.

CNS will continue piloting an asynchronous panel review process this fiscal year. A limited number of panels will be conducted this way. Rather than a face-to-face panel, the reviewers will conduct an asynchronous discussion on an access-controlled, moderated message board of the proposals that have been submitted. The most competitive proposals will then move on to a virtual panel review via teleconference for final recommendations. This pilot will continue to be evaluated within the larger context of NSF merit review pilots being conducted.

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

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

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

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

# VII. AWARD ADMINISTRATION INFORMATION

## A. Notification of the Award

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

## B. Award Conditions

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

*These documents may be accessed electronically on NSF's Website at http://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from

nsfpubs@nsf.gov.

More comprehensive information on NSF Award Conditions and other important information on the administration of NSF awards is contained in the NSF *Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag.

## C. Reporting Requirements

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

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

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

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the NSF *Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag.

## VIII. AGENCY CONTACTS

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

General inquiries regarding this program should be made to:

- Jack Brassil, NeTS Program Director, 1175, telephone: (703) 292-8950, email: jbrassil@nsf.gov

- Darleen L. Fisher, NeTS Program Director, 1175, telephone: (703) 292-8950, email: dlfisher@nsf.gov

- Wenjing Lou, NeTS Program Director, 1175, telephone: (703) 292-8950, email: wlou@nsf.gov

- Mimi McClure, CSR Associate Program Director, 1175, telephone: (703) 292-8950, email: mmcclure@nsf.gov

- Thyagarajan Nandagopal, NeTS Program Director, 1175, telephone: (703) 292-8950, email: tnandago@nsf.gov

- Gurdip Singh, CSR Program Director, 1175, telephone: (703) 292-8950, email: gsingh@nsf.gov

- Yan Solihin, CSR Program Director, 1175, telephone: (703) 292-7939, email: ysolihin@nsf.gov

For questions related to the use of FastLane, contact:

- FastLane Help Desk, telephone: 1-800-673-6188; e-mail: fastlane@nsf.gov.

For questions relating to Grants.gov contact:

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

## IX. OTHER INFORMATION

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

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

In addition to the *coordinated solicitation* discussed in this document, NSF provides funding opportunities for the computing community via the following programs and their solicitations:

**Discovery Research Programs**

Algorithms in the Field (AitF), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505125&org=CISE*

Collaborative Research in Computational Neuroscience (CRCNS), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5147&org=CISE*

Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505180&org=CISE*

Critical Techniques and Technologies for Advancing Foundations and Applications of Big Data Science & Engineering (BIGDATA), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504767&org=CISE*

Cultivating Cultures for Ethical STEM (CCE STEM), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505027&org=CISE*

Cyber-Physical Systems (CPS), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503286&org=CISE*

Emerging Frontiers in Research and Innovation (ERFI), http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13708

Energy-Efficient Computing: from Devices to Architectures (E2CDA), *http://www.nsf.gov/pubs/2016/nsf16526/nsf16526.htm?WT.mc_id=USNSF_25&WT.mc_ev=click*

Engineering Research Centers (ERCs), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5502&org=CISE*

Enhancing Access to the Radio Spectrum (EARS), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503480&org=CISE*

Expeditions in Computing, *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503169&org=CISE*

Exploiting Parallelism and Scalability (XPS), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504842&org=CISE*

Facilitating Research at Primarily Undergraduate Institutions, *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5518&org=CISE*

Faculty Early Career Development Program (CAREER), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503214&org=CISE*

Grant Opportunities for Academic Liaison with Industry (GOALI), *http://www.nsf.gov/pubs/2016/nsf16099/nsf16099.jsp*

Industry/University Cooperative Research Centers Program (I/UCRC), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5501&org=CISE*

Innovations at the Nexus of Food, Energy and Water Systems (INFEWS), http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505241

Innovation Corps Teams Program (I-Corps), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504672&org=CISE*

Integrative Strategies for Understanding Neural and Cognitive Systems (NSF-NCS), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505132&WT.mc_id=USNSF_39&WT.mc_ev=click*

National Robotics Initiative (NRI), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503641&org=CISE*

Partnerships for International Research and Education (PIRE), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505038&org=CISE*

Science and Technology Centers: Integrative Partnerships, *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5541&org=CISE*

Science of Learning: Collaborative Networks (SL-CN), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505176&org=CISE*

Secure and Trustworthy Cyberspace (SaTC), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504709&org=CISE*

Smart and Connected Health (SCH), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504739&org=CISE*

United States-Israel Collaboration in Computer Science (USICCS), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504828&org=CISE*

**Education and Workforce Development Programs**

ADVANCE: Increasing the Participation and Advancement of Women in Academic Science and Engineering Careers, *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5383&org=CISE*

Advanced Technological Education (ATE), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5464&org=CISE*

CISE Research Initiation Initiative (CRII), *https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504952*

Computer Science for All (CS for All), *http://www.nsf.gov/news/special_reports/csed/index.jsp?WT.mc_id=USNSF_51*

CyberCorps(R): Scholarship for Service (SFS), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504991&org=CISE*

Cyberlearning and Future Learning Technologies, *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504984&org=CISE*

Discovery Research K-12 (DRK-12), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=500047&org=CISE*

East Asia and Pacific Summer Institutes for US Graduate Students (EAPSI), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5284&org=CISE*

Graduate Research Fellowship Program (GRFP), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=6201&org=CISE*

Improving Undergraduate STEM Education (IUSE: EHR), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505082&org=CISE*

Information Technology Experiences for Students and Teachers (ITEST), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5467&org=CISE*

International Research Experiences for Students (IRES), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12831&org=CISE*

NSF Research Traineeship Program, *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505015&org=CISE*

NSF Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5257&org=CISE*

Research Experiences for Teachers (RET) in Engineering and Computer Science, *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505170&org=CISE*

Research Experiences for Undergraduates (REU), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5517&org=CISE*

STEM + Computing Partnerships (STEM+C), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505006&org=CISE*

**Research Infrastructure Programs**

Big Data Regional Innovation Hubs (BD Hubs), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505185&WT.mc_id=USNSF_39&WT.mc_ev=click*

Big Data Regional Innovation Hubs: Establishing Spokes to Advance Big Data Applications (BD Spokes), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=505264&WT.mc_id=USNSF_39&WT.mc_ev=click*

Campus Cyberinfrastructure -- Data, Networking, and Innovation Program (CC*DNI), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504748&org=CISE*

CISE Research Infrastructure (CRI), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=12810&org=CISE*

Cybersecurity Innovation for Cyberinfrastructure (CICI), *http://www.nsf.gov/pubs/2016/nsf16533/nsf16533.htm?WT.mc_id=USNSF_25&WT.mc_ev=click*

Data Infrastructure Building Blocks (DIBBs), *http://www.nsf.gov/pubs/2016/nsf16530/nsf16530.htm?WT.mc_id=USNSF_25&WT.mc_ev=click*

Major Research Instrumentation (MRI), *http://www.nsf.gov/od/iia/programs/mri/*

Petascale Computing Resource Allocations (PRAC), *http://www.nsf.gov/pubs/2016/nsf16529/nsf16529.htm?WT.mc_id=USNSF_25&WT.mc_ev=click*

Software Infrastructure for Sustained Innovation -- SSE & SSI ($SI^2$ -- SSE & SSI), *http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=504865&org=CISE*

For more information on these programs, please consult the NSF website.

## ABOUT THE NATIONAL SCIENCE FOUNDATION

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

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

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

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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**                 (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

     or telephone:                                   (703) 292-7827

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

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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.

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