

# Cyber-Physical Systems (CPS)

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## PROGRAM SOLICITATION NSF 08-611

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National Science Foundation

Directorate for Computer & Information Science & Engineering

Directorate for Engineering

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

February 27, 2009

Last Friday in February, Annually Thereafter

## SUMMARY OF PROGRAM REQUIREMENTS

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### General Information

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**Program Title:**

Cyber-Physical Systems (CPS)

**Synopsis of Program:**

The term cyber-physical systems refers to the tight conjoining of and coordination between computational and physical resources. We envision that the cyber-physical systems of tomorrow will far exceed those of today in terms of adaptability, autonomy, efficiency, functionality, reliability, safety, and usability. Research advances in cyber-physical systems promise to transform our world with systems that respond more quickly (e.g., autonomous collision avoidance), are more precise (e.g., robotic surgery and nano-tolerance manufacturing), work in dangerous or inaccessible environments (e.g., autonomous systems for search and rescue, firefighting, and exploration), provide large-scale, distributed coordination (e.g., automated traffic control), are highly efficient (e.g., zero-net energy buildings), augment human capabilities, and enhance societal wellbeing (e.g., assistive technologies and ubiquitous healthcare monitoring and delivery).

Congruent with the recommendations in the August 2007 report of the President's Council of Advisors on Science and Technology (PCAST), *Leadership Under Challenge: Information Technology R&D in a Competitive World*, NSF's Directorates for Computer and Information Science and Engineering (CISE) and Engineering (ENG) are spear-heading the Cyber-Physical Systems (CPS) program because of its scientific and technological importance as well as its potential impact on grand challenges in a number of sectors critical to U.S. security and competitiveness, including aerospace, automotive, chemical production, civil infrastructure, energy, healthcare, manufacturing, materials and transportation. By abstracting from the particulars of specific applications in these domains, the CPS program aims to reveal cross-cutting fundamental scientific and engineering principles that underpin the integration of cyber and physical elements across all application sectors. The CPS program will also support the development of methods and tools as well as hardware and software components, run-time substrates, and systems based upon these principles to expedite and accelerate the realization of cyber-physical systems in a wide range of applications. Furthermore, the program aims to create a new research and education community committed to the study and application of cyber-physical system innovations, through the establishment of a CPS Virtual Organization (CPS-VO) and regular PI meetings.

The CPS program is seeking proposals that address research challenges in three CPS themes: *Foundations*; *Methods and Tools*; and *Components, Run-time Substrates, and Systems*. *Foundations* research will develop new scientific and engineering principles, algorithms, models, and theories for the analysis and design of cyber-physical systems. Research on *Methods and Tools* will bridge the gaps between approaches to the cyber and physical elements of systems through innovations such as novel support for multiple views, new programming languages, and algorithms for reasoning about and formally verifying properties of complex integrations of cyber and physical resources. The third CPS theme concerns new hardware and software *Components, Run-time Substrates* (infrastructure and platforms), and (engineered) *Systems* motivated by grand challenge applications.

Three sizes of research and education projects will be considered:

- Small Projects are individual or small-team efforts that focus on one or more of the three defined CPS themes. Funding for Small Projects will be provided at levels of up to \$200,000/year for up to three years.
- Medium Projects also span one or more CPS themes and may include one or more PIs and a research team of students and/or postdocs. Funding for Medium Projects will be provided at levels up to \$500,000/year for up to three years.
- Large Projects are multi-investigator projects involving teams of researchers and their students and/or postdocs representing the same or multiple disciplines in computer science, engineering, and physical

application domains, who together address a coherent set of research issues that either cut across multiple CPS themes or that explore in great depth a particular theme. Funding for Large Projects will be provided at levels up to \$1,000,000/year for up to five years.

In addition, NSF will consider proposals to establish a CPS-VO. Only one award will be made, at annual levels of up to \$200,000 for up to five years. It is expected that more modest levels of funding will be provided in the first year or two of this award.

A more complete description of the CPS program is provided in Section II. *Program Description* of this solicitation.

**Cognizant Program Officer(s):**

- Helen Gill, CISE Point of Contact for the CPS program, telephone: (703) 292-7834, email: [hgill@nsf.gov](mailto:hgill@nsf.gov)
- Scott F. Midkiff, ENG Point of Contact for the CPS program, telephone: (703) 292-8339, email: [smidkiff@nsf.gov](mailto:smidkiff@nsf.gov)

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

- 47.041 --- Engineering
- 47.070 --- Computer and Information Science and Engineering

## Award Information

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

**Estimated Number of Awards:** 30 to 40 - NSF anticipates making up to 40 awards in the first competition. Three award size classes of research and education projects will be supported:

- Small Projects, up to \$200,000/year for up to three years;
- Medium Projects, up to \$500,000/year for up to three years; and
- Large Projects, up to \$1,000,000/year for up to five years.

In addition, no more than one CPS Virtual Organization (CPS-VO) award will be made at a level of up to \$200,000/year for up to five years. It is anticipated that the funding level for the CPS-VO will be more modest in the first year or two of the award.

**Anticipated Funding Amount:** \$30,000,000 - Approximately \$30 million for the first annual competition, dependent on the availability of funds. Anticipated funding levels for future competitions will be in the \$20 million - \$30 million range, dependent on the availability of funds.

## Eligibility Information

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**Organization Limit:**

Proposals may only be submitted by the following:

- 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.
- Universities and Colleges: Universities and two- and four-year colleges (including community colleges) located and accredited in the US, acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.

**PI Limit:**

None Specified

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

None Specified

**Limit on Number of Proposals per PI: 2**

An individual may participate as PI, co-PI, or Senior Personnel in no more than 2 proposals submitted in response to this solicitation in any annual competition.

## Proposal Preparation and Submission Instructions

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**A. Proposal Preparation Instructions**

- **Letters of Intent:** Not Applicable
- **Preliminary Proposal Submission:** Not Applicable
- **Full Proposals:**
  - Full Proposals submitted via FastLane: NSF Proposal and Award Policies and Procedures Guide, Part I: Grant Proposal Guide (GPG) Guidelines apply. The complete text of the GPG is available electronically on the NSF website at: [http://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=gpg](http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg).
  - Full Proposals submitted via Grants.gov: NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov Guidelines apply (Note: The NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at:

## B. Budgetary Information

- **Cost Sharing Requirements:** Cost Sharing is not required under this solicitation.
- **Indirect Cost (F&A) Limitations:** Not Applicable
- **Other Budgetary Limitations:** Not Applicable

## C. Due Dates

- **Full Proposal Deadline(s)** (due by 5 p.m. proposer's local time):
  - February 27, 2009
  - Last Friday in February, Annually Thereafter

## Proposal Review Information Criteria

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

## Award Administration Information

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**Award Conditions:** Additional award conditions apply. Please see the full text of this solicitation for further information.

**Reporting Requirements:** Standard NSF reporting requirements apply.

## TABLE OF CONTENTS

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### Summary of Program Requirements

- I. **Introduction**
- II. **Program Description**
- III. **Award Information**
- IV. **Eligibility Information**
- V. **Proposal Preparation and Submission Instructions**
  - A. Proposal Preparation Instructions
  - B. Budgetary Information
  - C. Due Dates
  - D. FastLane/Grants.gov Requirements
- VI. **NSF Proposal Processing and Review Procedures**
  - A. NSF Merit Review Criteria
  - B. Review and Selection Process
- VII. **Award Administration Information**
  - A. Notification of the Award
  - B. Award Conditions
  - C. Reporting Requirements
- VIII. **Agency Contacts**
- IX. **Other Information**

## I. INTRODUCTION

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The term cyber-physical systems refers to the tight conjoining of and coordination between computational and physical resources. We envision that the cyber-physical systems of tomorrow will far exceed those of today in terms of adaptability, autonomy, efficiency, functionality, reliability, safety, and usability. Research advances in cyber-physical systems promise to transform our world with systems that respond more quickly (e.g., autonomous collision avoidance), are more precise (e.g., robotic surgery and nano-tolerance manufacturing), work in dangerous or inaccessible environments (e.g., autonomous systems for search and rescue, firefighting, and exploration), provide large-scale, distributed coordination (e.g., automated traffic control), are highly efficient (e.g., zero-net energy buildings), augment human capabilities, and enhance societal wellbeing (e.g., assistive technologies and ubiquitous healthcare monitoring and delivery). These capabilities will be realized by deeply embedding computational intelligence, communication, control, and new mechanisms for sensing, actuation, and adaptation into physical systems with active and reconfigurable components.

We do not yet have the principles, methodologies, and tools needed to realize our vision for cyber-physical systems, where physical

and software components are deeply intertwined, each operating on different spatial and temporal scales, exhibiting multiple and distinct behavioral modalities, and interacting with each other in a myriad of ways that change with context. Despite the rapid growth of innovative and powerful technologies for networked computation, sensing, and control, progress in cyber-physical systems is impeded on several fronts. First, as the complexity of current systems has grown, the time needed to develop them has increased exponentially, and the effort needed to certify them has risen to account for more than half the total system cost. Second, the disparate and incommensurate formalisms and tools used to deal with the cyber and physical elements of existing systems have forced early and overly conservative design decisions and constraints that limit options and degrade overall performance and robustness. Third, in deployed systems, fears of unpredictable side-effects forestall even small software modifications and upgrades, and new hardware components remain on the shelf for want of true plug-and-play infrastructures. Fourth, current systems have limited ability to deal with uncertainty, whether arising from incidental events during operation or induced in systems development. These problems are endemic to the technology base for virtually every sector critical to U.S. security and competitiveness, and they will not be solved by finding point solutions for individual applications. The solutions that are needed are central to the gamut of cyber-physical system application domains. It is imperative that we begin to develop the cross-cutting fundamental scientific and engineering principles and methodologies that will be required to create the future systems upon which our very lives will depend.

The CPS program aims to discover this missing core of fundamental knowledge. Advances will be achieved by developing deep understanding of specific domains and technologies and abstracting this knowledge into core principles that can inform and be informed by other and yet-to-be-thought-of application domains. Grand challenge applications will inspire researchers to develop a better understanding of the coupling and interaction between computational and physical processes, the integration of the discrete with the continuous, and the synchronous with the asynchronous. Ensuing core principles will lead to the development of methods, tools, components, and architectures that will expedite and accelerate progress in a wide range of application domains. Rethinking the fundamental concepts and tools for cyber-physical systems will lead to possibilities for new systems that cannot be realized — or even envisioned — using today's methods and technologies.

The CPS program also aims to create a new research community that shares a commitment to integrate CPS theory and methodology in education. Through these investments, NSF seeks to promote increased interest, understanding, and use of cyber-physical systems through the development of novel educational curricula.

A premium will be placed on research and education innovations that span the boundaries of engineering and computer science.

## II. PROGRAM DESCRIPTION

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The CPS program seeks to establish bold new scientific foundations and engineering principles to conceptualize, design, analyze, implement, and certify cyber-physical systems. Tomorrow's cyber-physical systems will exploit pervasive sensing, computation, communication, and actuation to infuse engineered systems with considerably more intelligence and capabilities than is possible today. The CPS program will require a comprehensive effort from computer scientists, engineers, and physical domain experts to develop new theories, methods, and tools, as well as new hardware and software components, run-time substrates, and systems that will enable innovative systems for grand challenge applications. The research and education outcomes generated are expected to accelerate and transform our ability to understand and exploit the interfaces between the cyber and physical worlds and to innovate new behaviors and capabilities from their seamless integration.

The CPS program aims to develop a unifying theory for the design and implementation of integrated cyber and physical resources that can be applied across multiple domains. Currently, disparate methods are used to separately develop cyber and physical subsystems. The differences between the two sides are manifest at the most fundamental levels: computer science builds upon discrete mathematics, whereas engineering is dominated by continuous mathematics. Even within the broad fields of engineering and computer science, multiple sub-disciplines use incommensurate concepts and tools. Consequently, some systems are over-designed with wide margins to achieve isolation and separation of component interaction; where this is not possible due to price and performance concerns, it is difficult to assess the impact of design decisions in cyber-physical systems due to the lack of proper modeling abstractions for cross-cutting attributes. The lack of a unifying or composable theory makes it impossible to guarantee safety and performance by design. System verification requires extensive testing — an approach that is becoming intractable as systems become more complex.

Despite progress in the development of increasingly powerful technologies for networked embedded sensing and control, today's embedded computing systems are point solutions for specific applications. Current approaches to hardware and software design, systems engineering, and real-time control need to be rethought in the unifying context of cyber-physical systems. For example, open, flexible, and extensible architectures for cyber-physical systems would enable and better leverage advances in hardware and software substrates. They should be analyzable and support principled composition or integration. Run-time operation should exploit information-rich environments to enhance performance and reliability. In some applications, these systems should be context aware, with the ability to modify their behaviors to accommodate changing configurations, adapt to variations in the environment, sustain safe operation, and improve performance over time. For many applications, cyber-physical systems must be certifiable, which means new approaches are needed for the specification, verification, and validation of tightly integrated cyber and physical elements.

The CPS program aims to create a new research and education community that shares a commitment to develop new cyber-physical systems *Foundations*; *Methods and Tools*; and hardware and software *Components*, *Run-time Substrates*, and *Systems*. Together, this new multidisciplinary community will create unified approaches to developing and implementing fully integrated, robust, secure, failure-free cyber-physical systems. The CPS program will support transformative research focused on these issues as the principal concern. The program also encourages intentional integration of research and education aimed towards preparing a new cadre of CPS professionals.

All CPS research and education projects should address one or more of the following CPS themes:

*Foundations:* *Foundations* research will develop new scientific and engineering principles, theories, algorithms and models for the design and analysis of cyber-physical systems. Promising new theories will be inspired by specific application contexts, leading to new abstractions and general solutions, which in turn will be applicable to problems in multiple domains. CPS theories should lead to new techniques for assessing and exploiting the trade-offs in design alternatives that consider the cyber and physical elements of a system in a unified manner, comprehending both the discrete and continuous perspectives. New theories are needed to support abstraction, meta-modeling, and the integration of multiple models and views, for both discrete and continuous systems. These theories should encompass models and abstractions that span different levels of granularity — from detailed models (e.g., differential equations and process algebras), to reduced-order models for analysis, design, and simulation, to on-line models for run-time monitoring and control. New algorithms are needed for real-time coordination, cooperation, and autonomy in networks of cyber-physical systems, including systems with mobile

resources. These algorithms should enable cyber-physical systems that can operate reliably and safely in unpredictable and unstructured environments. Comprehensive theories and models for cyber-physical systems should also address human interfaces and cognitive issues.

*Methods and Tools:* The effective design of cyber-physical systems requires research advances in *Methods and Tools* that support multiple views of integrated cyber and physical components. New programming languages are needed to handle complex interactions between cyber and physical resources and to deal with unstructured data and stringent requirements for responsiveness. Algorithms for reasoning about, and formally verifying properties of, complex integrations of cyber and physical resources are needed. Tools for implementing algorithms to support off-line and run-time optimization and control are also needed. Tools should support concurrent engineering of physical systems (including materials, devices, and components) with sensing, communication, and control architectures. Methods and tools should enable new forms of analysis, testing, and validation of integrated discrete and continuous dynamics at multiple temporal and spatial scales and different levels of resolution. Tools should be open, interoperable, and highly expressive to enhance productivity and enable community use. They should also be extensible to leverage new results from the foundations research and accommodate new technologies from the *Components, Run-time Substrates, and Systems* research as they become available.

*Components, Run-time Substrates, and Systems:* The CPS program will support the development of new hardware and software *Components, Run-time Substrates* (infrastructure and platforms), and (engineered) *Systems* motivated by grand challenge applications. Hardware and software components, middleware, and operating systems for cyber-physical systems should go beyond today's technology, facilitating the deep integration of computation into physical processes and engineered systems through novel cyber-physical interfaces and innovative mechanisms to deal with complexity, timing, distribution, and uncertainty. Cyber-physical systems hardware and software substrates need to be highly dependable, composable, and certifiable at all levels, from components to fully integrated systems. Proposals addressing grand challenge applications should emphasize tightly integrated networks of cyber and physical resources that cannot be realized with today's technologies. Potential grand challenge applications can range in scale from networks of implantable biomedical devices, to teams of robotic resources for emergency response and disaster recovery, to innovations in the monitoring and control of future energy systems. Breakthrough cyber-physical systems should exhibit the ability to identify and predict changing contexts and adapt to new situations as they emerge. Cyber-physical system substrates and systems should be used to implement, demonstrate, and evaluate the *Foundations, Methods and Tools* also being developed with CPS program support.

## Types of Proposals

### i. Research and Education Proposals

Three sizes of research and education proposals will be accepted for Small, Medium, and Large Projects.

Small Projects are individual or small-team efforts that focus on one or more of the three defined CPS themes. Funding for Small Projects will be provided at levels of up to \$200,000/year for up to three years, although it is expected that the majority of Small Project awards will not exceed \$150,000/year for three years. Small Projects may be submitted as collaborative proposals (see NSF Grant Proposal Guide for definition), but the total budget for one set of collaborative proposals should not exceed \$200,000 per year.

Medium Projects also span one or more CPS themes and may include one or more PIs and a research team of students and/or postdocs. Funding for Medium Projects will be provided at levels up to \$500,000/year for up to three years. Medium Projects may be submitted as collaborative proposals (see NSF Grant Proposal Guide for definition), but the total budget for one set of collaborative proposals should not exceed \$500,000 per year.

Large Projects are multi-investigator projects involving teams of researchers and their students and/or postdocs representing the same or multiple disciplines in computer science, engineering, and physical application domains, who together address a coherent set of research issues that either cut across multiple CPS themes or that explore in great depth a particular theme. Funding for Large Projects will be provided at levels up to \$1,000,000/year for up to five years. Large Projects involving multiple institutions must be submitted as a single proposal from the lead institution, with subcontracts to the partner institutions.

Proposals submitted in each of these size classes must:

- describe how the project goals and research and education outcomes will contribute to the realization of the CPS program vision;
- focus on research contributions in one or more of the three CPS themes; innovative research that spans the boundaries of engineering and computer science is strongly encouraged;
- present a plan to integrate research outcomes into education;
- describe how the backgrounds of the proposer or proposing team cover the set of skills needed to realize the project goals; and
- provide plans for disseminating the research and education outcomes in a manner that helps scientists and engineers use the results in ways that go beyond traditional academic publications.

In addition, Large Project proposals **must** include:

- An Education and Outreach Plan describing: a) educational approaches that overcome traditional stove-piped curricula and better prepare students for careers in cyber-physical systems practice and research (new ideas for introducing prerequisites for, and stimulating interest in, cyber-physical systems in K-12 education are encouraged but not required); and b) one or more community-extending concepts, for example, programs to address the under-representation of women and minorities, or links to institutions with strong traditions of teaching, mentoring, and workforce development.
- A comprehensive Management Plan, detailing: a) the roles of the PIs and senior researchers in the project and how their activities will contribute to the project objectives; b) the mechanisms that will be used throughout the duration of the project to coordinate and integrate the activities of the participants, including a time-line for these coordination activities; and c) the management structure for the project, including identification of the individual who will be responsible for executing the management plan and the amount of the budget that will be allocated for project administration.

More information on the preparation of Large Project proposals is provided in *Section V. Proposal Preparation and Submission Instructions* of this solicitation.

### ii. CPS Virtual Organization (CPS-VO) Proposals

Proposals are sought to establish a CPS Virtual Organization (CPS-VO). CPS-VO proposals should describe innovative and effective strategies and mechanisms to: (i) facilitate and foster interaction and exchanges among CPS PIs and their teams; (ii) enable sharing of artifacts and knowledge generated by the projects with the broader engineering and scientific communities; and (iii) facilitate and foster collaboration and information exchange between CPS researchers and industry. Strategies and mechanisms could include, but are not limited to:

- creating and maintaining a web-based repository and collaborative platform to facilitate the open exchange of research results, tools, and educational materials among CPS researchers and the broader community;
- hosting tutorials and workshops to promote community interest, understanding, and the use of new methods;
- identifying effective mechanisms for technology transfer;
- creating a consortium of small businesses with interests in cyber-physical system innovations;
- collecting and disseminating cyber-physical system challenge problems from industry.

CPS-VO proposals do not need to identify the industry participants, but proposals may include a list of potential industry participants with accompanying letters of support. Note that NSF will not provide funding to industry participants through the CPS-VO award; industry participants will be expected to cover their own time and expenses to participate in teleconferences, meetings, and other activities organized by the CPS-VO.

No more than one CPS-VO proposal will be funded. Funding of up to \$200,000/year for up to five years may be requested, although funding provided is likely to be more modest in the CPS-VO's first year or two. The CPS-VO will be funded as a continuing grant, with an annual review.

#### **CPS PI Meetings**

The CPS program aims to build a new research and education community, including computer scientists, engineers, and experts in physical, chemical, biological, and social systems. To help establish this community, the CPS program will host annual meetings with participation from all funded projects and other representatives from government, industry, and the research community to facilitate the exchange of concepts, ideas, and outcomes and to encourage collaborations that cut across projects and the three CPS themes. Industry participants will provide perspectives on emerging cyber-physical systems applications and identify opportunities for industrial collaboration and technology transfer.

#### **CPS Industry Participation**

Through the CPS-VO described above, industry will frame key industrial cyber-physical systems challenges and emerging application domains and track progress in relevant projects in the CPS program. These challenges and application domains will be presented to CPS PIs to inform and motivate research projects in all three CPS themes. PIs will be encouraged to work with industry through the CPS-VO to develop the aspects of target applications that will serve best to demonstrate and evaluate their research results. To accelerate knowledge transfer developed in the CPS program, NSF will consider providing support through other existing programs, such as the Small Business Innovation Research (SBIR) program, the Industry/University Cooperative Research Center (I/UCRC) program, and the Grant Opportunities for Academic Liaison with Industry (GOALI) program.

### **III. AWARD INFORMATION**

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Approximately \$30,000,000 will be available for the first annual competition, pending the availability of funds. Anticipated funding levels for future competitions will be in the \$20 million - \$30 million range, dependent on the availability of funds. NSF anticipates making up to 40 awards in the first annual competition.

Three award size classes of research and education projects will be supported: Small Projects, up to \$200,000/year for up to three years; Medium Projects, up to \$500,000/year for up to three years; and Large Projects, up to \$1,000,000/year for up to five years.

In addition, one CPS Virtual Organization (CPS-VO) will be funded at a level of up to \$200,000/year for up to five years. It is anticipated that the funding level for the CPS-VO will be more modest in the first year or two of the award.

Budgets for all projects must include funding for project representatives (PI/co-PI/senior researchers and graduate students) to attend the annual CPS PI Meetings. Budgets may also include support for Ph.D. students to visit other institutions, government labs, or industry to engage in collaborative research.

### **IV. ELIGIBILITY INFORMATION**

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#### **Organization Limit:**

Proposals may only be submitted by the following:

- 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.
- Universities and Colleges: Universities and two- and four-year colleges (including community colleges) located and accredited in the US, acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.

#### **PI Limit:**

None Specified

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



None Specified

#### Limit on Number of Proposals per PI: 2

An individual may participate as PI, co-PI, or Senior Personnel in no more than 2 proposals submitted in response to this solicitation in any annual competition.

#### Additional Eligibility Info:

**These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently.** Any individual listed as a PI/co-PI or whose biographical sketch is provided as part of the proposed activity will be considered Senior Personnel in the activity. If a person appears on more than two proposals, all proposals in which that individual is participating 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 this solicitation.

## V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

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### A. Proposal Preparation Instructions

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

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the NSF Grant Proposal Guide (GPG). The complete text of the GPG is available electronically on the NSF website at: [http://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=gpg](http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg). Paper copies of the GPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from [pubs@nsf.gov](mailto:pubs@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/bfa/dias/policy/docs/grantsgovguide.pdf>). 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 [pubs@nsf.gov](mailto:pubs@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.3 of the Grant Proposal Guide provides additional information on collaborative proposals.

The following information supplements guidelines provided in the NSF Grant Proposal Guide (GPG) and the NSF Grants.gov Application Guide:

**Proposal Titles:** Proposal titles must indicate the CPS program, followed by a colon, then the project type, followed by a colon, then the title of the project. For example, a Large Project proposal title would be **CPS:Large:Title**, and a CPS-VO proposal title would be **CPS:VO:Title**. Titles of collaborative proposals should be prepared as above, but should also include "Collaborative Research" followed by a colon before the title of the project. For example, the title of each proposal for a collaborative set of proposals for a Medium Project would be **CPS:Medium:Collaborative Research:Title**. Proposals from PIs in institutions that have RUI (Research in Undergraduate Institutions) eligibility should also include "RUI" followed by a colon as the last identifier before the project title, for example, **CPS:Small:RUI:Title**.

In **Research and Education Proposals**, identify the CPS theme(s) being addressed in the proposed project (i.e., *Foundations; Methods and Tools; and/or Components, Run-time Substrates, and Systems*) in **both** the Project Summary and in the Project Description.

Proposals submitted in each of the Small, Medium, and Large Project size classes must:

- describe how the project goals and research and education outcomes will contribute to the realization of the CPS program vision;
- focus on research contributions in one or more of the three CPS themes;
- present a plan to integrate research outcomes into education;
- describe how the backgrounds of the proposer or proposing team cover the set of skills needed to realize the project goals; and
- provide plans for disseminating the research and education outcomes in a manner that helps scientists and engineers use the results in ways that go beyond traditional academic publications.

In addition, Large Project proposals **must** include an Education and Outreach Plan **within the 15-page Project Description** that describes: a) educational approaches that overcome traditional stove-piped curricula and better prepare students for careers in cyber-physical systems practice and research (new ideas for introducing

prerequisites for, and stimulating interest in, cyber-physical systems in K-12 education are encouraged but not required); and b) one or more community-extending concepts, for example, programs to address the under-representation of women and minorities, or links to institutions with strong traditions of teaching, mentoring, and workforce development.

Further, Large Project proposals **must** also include a Management Plan detailing: a) the roles of the PIs and senior researchers in the project and how their activities will contribute to the project objectives; b) the mechanisms that will be used throughout the duration of the project to coordinate and integrate the activities of the participants, including a time-line for these coordination activities; and c) the management structure for the project, including identification of the individual who will be responsible for executing the management plan and the amount of the budget that will be allocated for project administration. Proposals involving researchers from more than a single institution must provide a compelling rationale for the multi-institutional structure of the project and a well-constructed Management Plan that assures effective collaboration. The Management Plan should not exceed 5 pages and **should be uploaded into the Supplementary Docs section in FastLane or Grants.gov**.

Remember that Large Projects involving multiple institutions must be submitted as a single proposal from the lead institution, with subcontracts to the partner institutions.

In **CPS-VO Proposals**, describe innovative and effective strategies and mechanisms to: (i) facilitate and foster interaction and exchanges among CPS PIs and their teams; (ii) enable sharing of artifacts and knowledge generated by the projects with the broader engineering and scientific communities; and (iii) facilitate and foster collaboration and information exchange between CPS researchers and industry.

#### Supplementary Documents for Institutions that have RUI Eligibility

PIs from predominantly undergraduate institutions should also include a Research in Undergraduate Institutions (RUI) Impact Statement and Certification of RUI Eligibility in the Supplementary Documents section.

**Impact Statement.** All RUI proposals must include a RUI Impact Statement (maximum length 5 pages). The statement is an opportunity to provide information that a reviewer will find helpful in assessing the likely impact of the proposed research activity on the research environment of the predominantly undergraduate institutions(s), on the career(s) of the faculty participants, and on the ability of the involved department(s) to prepare students for entry into advanced-degree programs and/or careers in science and engineering. An enhanced departmental environment may be reflected in direct student training in research and in increased involvement of the faculty in competitive research, which in turn leads to improved student preparation. It may also be reflected in curricular impact and faculty development.

The RUI Impact Statement should highlight the record of the department(s) and institution(s) in educating undergraduates for science and engineering careers; the plans to attract qualified undergraduate students to the project, including the criteria for their selection; provisions that will increase the participation of groups underrepresented in science and engineering; and any plans for measuring the effect of participation in the project on the participating students both during and after their undergraduate years. Also of interest is the anticipated contribution of new research tools (instrumentation, databases, etc.) to both educational and research opportunities for students and faculty.

The Impact Statement may include information on factors affecting research productivity such as teaching loads, availability (or lack) of support personnel, nature of experimental and computational facilities, and features of the student population. It may also describe institutional support for research activity by faculty and students and the anticipated impact of that support on the proposed project.

**Certification of RUI Eligibility.** The following Certification, executed by an Authorized Institutional Representative, must be provided in RUI proposals. The signed Certification should be scanned and included in the proposal as Supplementary Documentation. Institutions are allowed some leeway in the period over which the number of doctorates is averaged, in order to avoid negative effects of short-term anomalies in the number of doctorates awarded.

-----Certification of RUI Eligibility-----

"By submission of this proposal, the institution hereby certifies that the originating and managing institution is an institution that offers courses leading to a bachelor's or master's degree, but has awarded an average of no more than 10 doctoral degrees per year in NSF-supported disciplines over the 2-to-5-year period preceding proposal submission."

Authorized Institutional Representative

\_\_\_\_\_  
Typed Name and Title.....Signature.....Date.....

## B. Budgetary Information

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**Cost Sharing:** Cost sharing is not required under this solicitation.

#### Budget Preparation Instructions:

Budgets for all projects must include funding for project representatives (PI/co-PI/senior researchers and graduate students) to attend the annual CPS PI Meetings. Budgets may also include support for students and postdocs to visit other institutions, government labs, or industry for collaborative research.

## C. Due Dates

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

February 27, 2009



## D. FastLane/Grants.gov Requirements

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- **For Proposals Submitted Via FastLane:**

Detailed technical instructions regarding the technical aspects of preparation and submission via FastLane are available at: <https://www.fastlane.nsf.gov/a1/newstan.htm>. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail [fastlane@nsf.gov](mailto:fastlane@nsf.gov). The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

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

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

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. The Grants.gov's Grant Community User Guide is a comprehensive reference document that provides technical information about Grants.gov. Proposers can download the User Guide as a Microsoft Word document or as a PDF document. The Grants.gov User Guide is available at: <http://www.grants.gov/CustomerSupport>. In addition, the NSF Grants.gov Application Guide provides additional technical guidance regarding preparation of proposals via Grants.gov. For Grants.gov user support, contact the Grants.gov Contact Center at 1-800-518-4726 or by email: [support@grants.gov](mailto:support@grants.gov). The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this solicitation.

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

## VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

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Proposals received by NSF are assigned to the appropriate NSF program where they will be reviewed if they meet NSF proposal preparation requirements. 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 who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with the 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.

### A. NSF Merit Review Criteria

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All NSF proposals are evaluated through use of the two National Science Board (NSB)-approved merit review criteria: intellectual merit and the broader impacts of the proposed effort. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

The two NSB-approved merit review criteria are listed below. The criteria include considerations that help define them. These considerations are suggestions and not all will apply to any given proposal. While proposers must address both merit review criteria, reviewers will be asked to address only those considerations that are relevant to the proposal being considered and for which the reviewer is qualified to make judgements.

**What is the intellectual merit of the proposed activity?**

How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of the prior work.) To what extent does the proposed activity suggest and explore creative, original, or potentially transformative concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

**What are the broader impacts of the proposed activity?**

How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

Examples illustrating activities likely to demonstrate broader impacts are available electronically on the NSF website at: <http://www.nsf.gov/pubs/gpg/broaderimpacts.pdf>.

NSF staff also will give careful consideration to the following in making funding decisions:

**Integration of Research and Education**

One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

#### ***Integrating Diversity into NSF Programs, Projects, and Activities***

Broadening opportunities and enabling the participation of all citizens -- women and men, underrepresented minorities, and persons with disabilities -- 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.

#### **Additional Review Criteria:**

All proposals will be evaluated with respect to their emphasis on holistic, integrative approaches to cyber-physical systems and the extent to which they address specific CPS theme(s). Large Project proposals will also be evaluated on the strength of their education and outreach programs and management plans.

## **B. Review and Selection Process**

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

Reviewers will be asked to formulate a recommendation to either support or decline each proposal. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

After scientific, technical and programmatic review and consideration of appropriate factors, the NSF Program Officer recommends to the cognizant Division Director whether the proposal should be declined or recommended for award. NSF is striving to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. The time interval begins on the deadline or target date, or receipt date, whichever is later. The interval ends when the Division Director accepts the Program Officer's recommendation.

A summary rating and accompanying narrative will be completed and submitted by each reviewer. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers, are sent to the Principal Investigator/Project Director by the Program Officer. In addition, the proposer will receive an explanation of the decision to award or decline funding.

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

## **VII. AWARD ADMINISTRATION INFORMATION**

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### **A. Notification of the Award**

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

### **B. Award Conditions**

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

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

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

**Special Award Conditions:** Special award conditions will require that designated CPS project representatives (PI/co-PI/senior researchers and graduate students) attend annual CPS PI meetings, and participate in collaborative activities with the CPS-VO.

## **C. Reporting Requirements**

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For all multi-year grants (including both standard and continuing grants), the Principal Investigator must submit an annual project report to the cognizant Program Officer at least 90 days before the end of the current budget period. (Some programs or awards require more frequent project reports). Within 90 days after expiration of a grant, the PI also is required to submit a final project report.

Failure to provide the required annual or final project reports will delay NSF review and processing of any future funding increments as well as any pending proposals for that PI. 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 FastLane, for preparation and submission of annual and final project reports. Such reports provide information on activities and findings, project participants (individual and organizational) publications; and, other specific products and contributions. PIs will not be required to re-enter information previously provided, either with a proposal or in earlier updates using the electronic system. Submission of the report via FastLane constitutes certification by the PI that the contents of the report are accurate and complete.

## VIII. AGENCY CONTACTS

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General inquiries regarding this program should be made to:

- Helen Gill, CISE Point of Contact for the CPS program, telephone: (703) 292-7834, email: [hgill@nsf.gov](mailto:hgill@nsf.gov)
- Scott F. Midkiff, ENG Point of Contact for the CPS program, telephone: (703) 292-8339, email: [smidkiff@nsf.gov](mailto:smidkiff@nsf.gov)

For questions related to the use of FastLane, contact:

- FastLane Help Desk, telephone: 1-800-673-6188; e-mail: [fastlane@nsf.gov](mailto:fastlane@nsf.gov).

For questions relating to Grants.gov contact:

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

Drs. Gill and Midkiff will be assisted by the following CISE-ENG Program Officer team:

- Dr. Kishan Baheti, ENG, email: [rbaheti@nsf.gov](mailto:rbaheti@nsf.gov), telephone: (703) 292-8339
- Dr. Michael Branicky, CISE, email: [mbranick@nsf.gov](mailto:mbranick@nsf.gov), telephone: (703) 292-8950;
- Dr. Paul Oh, CISE, email: [poh@nsf.gov](mailto:poh@nsf.gov), telephone: (703) 292-8930;
- Dr. Usha Varshney, ENG, email: [uvarshne@nsf.gov](mailto:uvarshne@nsf.gov), telephone: (703) 292-8339; and
- Dr. Lenore Zuck, CISE, email: [lzuck@nsf.gov](mailto:lzuck@nsf.gov), telephone: (703) 292-8910.

## IX. OTHER INFORMATION

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The NSF Website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this Website by potential proposers is strongly encouraged. In addition, MyNSF (formerly the Custom News Service) 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 Regional 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. MyNSF also is available on NSF's Website at <http://www.nsf.gov/mynsf/>.

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

## ABOUT THE NATIONAL SCIENCE FOUNDATION

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

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

NSF receives approximately 40,000 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 Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US

participation in international scientific and engineering efforts, and educational activities at every academic level.

*Facilitation Awards for Scientists and Engineers with Disabilities* provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See Grant Proposal Guide Chapter II, Section D.2 for instructions regarding preparation of these types of proposals.

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

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

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

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

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

## PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

The information requested on proposal forms and project reports is solicited under the authority of the National Science Foundation Act of 1950, as amended. The information on proposal forms will be used in connection with the selection of qualified proposals; and project reports submitted by awardees will be used for program evaluation and reporting within the Executive Branch and to Congress. The information requested may be disclosed to qualified reviewers and staff assistants as part of the proposal review process; to proposer institutions/grantees to provide or obtain data regarding the proposal review process, award decisions, or the administration of awards; to government contractors, experts, volunteers and researchers and educators as necessary to complete assigned work; to other government agencies or other entities needing information regarding applicants or nominees as part of a joint application review process, or in order to coordinate programs or policy; and to another Federal agency, court, or party in a court or Federal administrative proceeding if the government is a party. Information about Principal Investigators may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See Systems of Records, NSF-50, "Principal Investigator/Proposal File and Associated Records," 69 Federal Register 26410 (May 12, 2004), and NSF-51, "Reviewer/Proposal File and Associated Records," 69 Federal Register 26410 (May 12, 2004). Submission of the information is voluntary. Failure to provide full and complete information, however, may reduce the possibility of receiving an award.

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

Suzanne H. Plimpton  
Reports Clearance Officer  
Division of Administrative Services  
National Science Foundation  
Arlington, VA 22230

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

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