Cyber-Physical Systems (CPS)

PROGRAM SOLICITATION
NSF 13-502

REPLACES DOCUMENT(S):
NSF 12-520

National Science Foundation

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

Directorate for Engineering
Division of Electrical, Communications and Cyber Systems
Division of Civil, Mechanical and Manufacturing Innovation

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

January 14, 2013 - January 29, 2013

January 14 - January 29, Annually Thereafter

IMPORTANT INFORMATION AND REVISION NOTES

Revision Summary

The Cyber-Physical Systems program solicitation has minor revisions for the FY 2013 competition. You are advised to read the solicitation carefully. Among the significant changes, the following are worthy of special notice:

- The Breakthrough proposal category is refocused on research that bridges the areas of computing, communication, and control.
- The ranges of funding levels for all proposal categories have been revised.
- The page limit for the Project Description section of Synergy and Frontiers proposals has been increased to 20 pages.

The CPS program is cooperating with other government agencies to support cyber-physical systems research that is relevant to their missions. Dear Colleague Letters will announce these opportunities as they arise.

Important Reminders

- Breakthrough proposals have additional requirements for Supplementary Documents.
- Frontiers proposals have additional requirements for Supplementary Documents.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Cyber-Physical Systems (CPS)

Synopsis of Program:

Cyber-physical systems (CPS) are engineered systems that are built from and depend upon the synergy of computational and physical components. Emerging CPS will be coordinated, distributed, and connected, and must be robust and responsive. The CPS of tomorrow will need to far exceed the systems of today in capability, adaptability, resiliency, safety, security, and usability. Examples of the many CPS application areas include the smart electric grid, smart transportation, smart buildings, smart medical technologies, next-generation air traffic management, and advanced manufacturing. CPS will transform the way people interact with engineered systems, just as the Internet transformed the way people interact with information. However, these goals cannot be achieved without rigorous systems engineering.

The December 2010 report of the President's Council of Advisors on Science and Technology, *Designing a Digital Future: Federally Funded Research and Development in Networking and Information Technology* calls for continued investment in CPS research 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.

We do not yet have a mature science to support systems engineering of high confidence CPS, and the consequences are profound. Traditional analysis tools are unable to cope with the full complexity of CPS or

adequately predict system behavior. The present electric power grid, an ad hoc system, experiences blackouts over large regions, tripped by minor events that escalate with surprising speed into widespread power failures. This illustrates the limitations of the current science and technology, which do not enable us to conceptualize and design for the deep interdependencies among engineered systems and the natural world. At the same time, pressure to develop technologies such as renewable energy, wireless health, advanced manufacturing, smart materials, and electrified ground and air vehicles creates an unprecedented opportunity to rethink many important classes of systems.

The goal of the CPS program is to develop the core system science needed to engineer complex cyber-physical systems upon which people can depend with high confidence. The program aims to foster a research community committed to advancing research and education in CPS and to transitioning CPS science and technology into engineering practice. By abstracting from the particulars of specific systems and application 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. To expedite and accelerate the realization of cyber-physical systems in a wide range of applications, the CPS program also supports the development of methods, tools, and hardware and software components based upon these cross-cutting principles, along with validation of the principles via prototypes and test beds.

Three types of research and education projects will be considered, which differ in scope and goals:

- Breakthrough projects must offer a significant advance in fundamental CPS science, engineering and/or technology that has the potential to change the field. This category focuses on new approaches to bridge computing, communication, and control. Funding for Breakthrough projects may be requested for a total of up to $500,000 for a period of up to 3 years.
- Synergy projects must demonstrate innovation at the intersection of multiple disciplines, to accomplish a clear goal that requires an integrated perspective spanning the disciplines. Funding for Synergy projects may be requested for a total of $500,001 to $1,000,000 for a period of 3 to 4 years.
- Frontiers projects must address clearly identified critical CPS challenges that cannot be achieved by a set of smaller projects. Funding may be requested for a total of $1,000,001 to $7,000,000 for a period of 4 to 5 years.

The CPS program is cooperating with other government agencies to support cyber-physical systems research that is relevant to their missions. Dear Colleague Letters will announce these opportunities as they arise.

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

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.

- Helen Gill, CISE Point of Contact for the CPS program, 1175, telephone: (703) 292-7834, email: hgill@nsf.gov
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- Radhakisan Baheti, ENG Point of Contact for the CPS program, 525, telephone: (703) 292-8339, email: rbaheti@nsf.gov
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- Ralph Wachter, Program Director, CISE/CNS, 1175, telephone: (703) 292-8950, email: rwachter@nsf.gov

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

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

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 20 to 32

This includes up to 10 Breakthrough projects, up to 20 Synergy projects, and up to 2 Frontiers projects.

Anticipated Funding Amount: $32,000,000 approximately for each annual competition, dependent on the availability of funds.

Eligibility Information

Organization Limit:

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.

PI Limit:

None Specified

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI or Co-PI: 2

An individual must not participate as PI, co-PI, or Senior Personnel in more than 2 proposals submitted in response to this solicitation in any annual competition.

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. In the event that an individual exceeds the two-proposal limit for this solicitation, 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).

Proposal Preparation and Submission Instructions

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.
  - 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. proposer's local time):

  January 14, 2013 - January 29, 2013

  January 14 - January 29, Annually Thereafter

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

Reporting Requirements: Standard NSF reporting requirements apply.

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I. INTRODUCTION

Cyber-physical systems (CPS) are engineered systems that are built from and depend upon the synergy of computational and physical components. Emerging CPS will be coordinated, distributed, and connected, and must be robust and responsive. The CPS of tomorrow will far exceed the simple embedded systems of today in capability, adaptability, resiliency, safety, security, and usability. CPS technology will transform the way people interact with engineered systems, just as the Internet transformed the way people interact with information. New smart cyber-physical systems will drive innovation and competition in sectors such as the power grid, transportation, buildings, medicine, and manufacturing.

We do not yet have a mature science to support systems engineering of high confidence CPS, and the consequences are profound. Traditional analysis tools are unable to cope with the full complexity of CPS or adequately predict system behavior. For example, the current electric power grid, an ad hoc system, experiences blackouts over large regions, tripped by minor events that escalate with surprising speed into widespread power failures. This exemplifies the lack of appropriate science and technology to conceptualize and design for the deep interdependencies among engineered systems and the natural world. The challenges and opportunities for CPS are significant and far reaching. New relationships between the cyber and physical components require new architectural models that redefine form and function. They intertwine the continuous and discrete, compounded by the uncertainty of open environments. Traditional real-time performance guarantees are insufficient for CPS when systems are large, and spatially and temporally distributed in arrangements that may rapidly change. With the greater autonomy and cooperation possible with CPS, greater assurances of safety, security, scalability, and reliability are demanded. This places a high premium on open interfaces, modularity, interoperability, and verification.

The CPS program seeks to develop the core system science needed to engineer complex cyber-physical systems upon which people can depend with high confidence. The program aims to foster a research community committed to advancing research and education in CPS and to transitioning CPS science and technology into engineering practice.

II. PROGRAM DESCRIPTION

The goal of the Cyber-Physical Systems (CPS) program is to establish the scientific foundations and engineering principles needed to realize cyber-physical systems with capability and dependability far beyond what we are able to achieve today.

To reach this goal, CPS foundations and engineering principles must surmount challenges that are ubiquitous and fundamental for this class of systems. For example, CPS involve the interaction of both cyber and physical components, whose dynamics have historically been modeled separately but need to be modeled jointly in terms of the discrete, continuous, and perhaps uncertain behaviors of the system and its environment. CPS increasingly are autonomous or semi-autonomous and cannot be designed as closed systems that operate in isolation; rather, the interaction and potential interference among smart components, among CPS, and among CPS and humans requires coordinated, controlled, and cooperative behavior. Prior formulations of real-time guarantees do not suffice for CPS; new concepts need to be devised for systems that are spatially and temporally distributed, possibly in ad hoc configurations, yet require temporal assurances. CPS will be designed and built in the context of dynamic supply chains, rather than by a single manufacturer with strict control over all interfaces; foundations and engineering principles must address CPS that are open and modular. Adequate solutions to these problems, as well as to the many others not listed here, will require an integrated perspective of real-time computing, communication, dynamics, and control for CPS.

The CPS program takes a coordinated approach that balances theory with experimentation, and systematic advances with revolutionary breakthroughs. The program seeks cross-disciplinary collaborative research that will lead to new fundamental insights. The program encourages empirical validation of new concepts through research prototypes, ranging from component devices to entire systems.

The vision of the CPS program can only be achieved by an engaged, multi-disciplinary CPS research and education community committed to developing unified foundations, principles, and technologies for CPS and demonstrating their effectiveness on challenging problems of societal importance. The program seeks ideas for incorporating this new science into education that will prepare a CPS workforce for tomorrow.

Research Target Areas. While the CPS program welcomes proposals that address research issues across a wide range of issues in CPS, a proposal must address at least one of the three Research Target Areas: Science of Cyber-Physical Systems, Technology for Cyber-Physical Systems, and Engineering of Cyber-Physical Systems.

Science of Cyber-Physical Systems: The classical models of computation and physics are separately inadequate to capture the semantics of CPS. CPS require new models and theories that unify perspectives, capable of expressing the interacting dynamics of the computational and physical components of a system in a dynamic environment. A unified science would support composition, bridge the computational versus physical notions of time and space, cope with uncertainty, and enable cyber-physical systems to interoperate and evolve.

Technology for Cyber-Physical Systems: New design, analysis, and verification tools are needed that embody the scientific principles of CPS, and that incorporate measurement, dynamics, and control. The tools should offer important perspectives into behaviors and interactions. New building blocks are also needed, including hardware computing platforms, operating systems, and middleware. The chain of tools and building blocks must integrate to support end-to-end assurances, and cover the full lifecycle of systems. Particular attention should be given to interfaces, interface management, extensibility, interoperability, and the controlled visibility of explicit and implicit assumptions. A particular goal is to enable evidence-based certification, and maintain certification as

a system evolves.

Engineering of Cyber-Physical Systems: CPS opens a new opportunity to rethink the principles and methods of systems engineering, built on the foundation of CPS science and technology and able to support open cyber-physical systems. Attention should be given to system architecture, design, integration, and design space exploration that produce certifiably dependable systems. New engineering principles are needed to systematize design for the growing numbers of CPS that entail adaptation and autonomy. All advances should be assessed and validated for relevance, usability, and effectiveness by appropriate benchmarks. The engineering processes must support certification and maintenance of certification over the system lifecycle.

Projects that integrate CPS advances into upper level undergraduate and introductory graduate curricula are encouraged.

Challenge Applications. The program welcomes projects that explore next-generation CPS applications in conjunction with research in one or more of the three CPS Research Target Areas. Such projects should incorporate careful experimentation designed to inform CPS science and technology. Systems of interest will be at the same time transformative and translational, demonstrating inventive new ideas and multi-disciplinary technical approaches to societal challenges. Challenge applications can range from extremely focused inventions enabled by CPS technology to revolutionary approaches to next-generation infrastructures. The CPS program encourages projects that address concerns shared with other federal agencies, such as transportation, medicine, manufacturing, agriculture, energy, and national security. The CPS program especially welcomes projects that address renewable energy, advanced manufacturing, and automation for vehicle and highway safety.

The CPS program is cooperating with other government agencies to support cyber-physical systems research that is relevant to their missions. Dear Colleague Letters will announce these opportunities as they arise.

Experimentation in CPS Projects. Principled experimentation, prototyping, and validation are expected for all CPS projects, and experimentation on an actual cyber-physical system is required for projects of greater than three (3) years.

Experimentation that involves humans or animals, whether directly as in medical research or indirectly in cyberspace, must be in accordance with ethical guidelines and approved by the organization's Institutional Review Board. Active engagement with industry and other academic institutions is strongly encouraged; any such unfunded collaboration should be documented by letters of commitment.

Types of Proposals. The following three types of research and education proposals that differ in scope and goals, which require different funding levels and durations, will be accepted:

Breakthrough Projects: The proposed research should clearly identify and explain a major advance in fundamental CPS science and/or CPS technology that bridges scientific or technology gaps between computing, communication, and control and achieves new capability for high-confidence real-time and embedded systems, real-time data management and processing, and/or secure networked real-time control. Successful research is expected to open a new research direction that will significantly change the field. Proposals for Breakthrough projects are *required to have a statement of* ***up to one page*** persuasively arguing why the research, if successful, would significantly change the field of cyber-physical systems. This statement must be submitted as a document under Supplementary Documentation. Proposal budgets may be up to $500,000 per project total cost, for a period of up to 3 years. No more than 10 awards are anticipated in FY13.

Synergy Projects: The proposed research should demonstrate innovation at the intersection of multiple disciplines. It must have a clear goal that reflects a shared perspective, crossing the disciplines and achieving integration. The proposal must explain the synergy that will be achieved by the collaboration. Proposal budgets must be between $500,001 and $1,000,000 per project total cost, for a period of 3 to 4 years. Approximately 20 awards are anticipated in FY13.

Frontiers Projects: The proposal must clearly identify and address critical CPS science, engineering or technological challenges that cannot be achieved by a set of smaller projects. The goal, scale, and degree of integration of the proposed research must clearly require this major investment. The research plan must include validation of theory through empirical demonstration in a prototype or test-bed. There must be a plan for sharing results, including test-bed and artifacts, with the CPS research community, through the CPS Virtual Organization, as well as a plan for transition to practice, involving potential end users and stakeholders. Proposal budgets may be from $1,000,001 to $7,000,000 per project total cost, for a period of 4 to 5 years. Up to 2 awards are anticipated in FY13.

The CPS program also encourages applications from groups eligible to compete as RUI (Research in Undergraduate Institutions - NSF 00-144) or GOALI (Grants Opportunities for Academic Liaison with Industry- NSF 10-580) under the CPS program deadlines.

Additional Requirements for all CPS Proposals.

Important requirements for the preparation of proposals are provided in Section V. Proposal Preparation and Submission Instructions of this solicitation.

All CPS proposals are expected to bridge traditional disciplinary boundaries. Team composition must reflect expertise and contribution in each of the disciplinary areas for which integration is claimed.

Research focusing exclusively on a topic covered within an existing NSF core disciplinary program should be submitted to that program.

Supplements. Opportunities may be announced for supplements to current CPS awards to support cross-project or cross-agency collaborations, international collaborations, technology maturation, educational development, and translational research. Any such announcements from the CPS program will be by Dear Colleague Letters. Supplemental proposals that are not in response to a specific announcement require prior agreement from the CPS program management team.

CPS PI Meetings and CPS Virtual Organization. The CPS program aims to build a new research and education community. In this spirit, the program hosts annual meetings with participation from all funded projects and other representatives from the research community, government, and industry. The program also sponsors the CPS Virtual Organization (CPS-VO) (http://www.cps-vo.org/), a broad community of interest for CPS researchers and developers. Principal Investigators are expected to participate in the annual meetings and encouraged to use the CPS-VO to coordinate activities and share artifacts and research results.

Other Funding Opportunities. The CPS program notes the CRI (Computing Research Infrastructure - NSF 11-536) and MRI (Major Research Instrumentation - NSF 11-503) programs as potential sources of funding for community infrastructure and experimental test beds for CPS research. Expeditions in Computing (NSF 10-564) provides the CISE research and education community with the opportunity to pursue ambitious, fundamental research agendas that promise to define the future of computing.

III. AWARD INFORMATION

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 20 to 32

This includes up to 10 Breakthrough projects, up to 20 Synergy projects, and up to 2 Frontiers projects.

Anticipated Funding Amount: $32,000,000 approximately for each annual competition, dependent on the availability of funds.

IV. ELIGIBILITY INFORMATION

Organization Limit:

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.

PI Limit:

None Specified

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI or Co-PI: 2

An individual must not participate as PI, co-PI, or Senior Personnel in more than 2 proposals submitted in response to this solicitation in any annual competition.

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. In the event that an individual exceeds the two-proposal limit for this solicitation, 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).

Additional Eligibility Info:

The Organization Limit above does not preclude eligible organizations from submitting proposals that involve participation of for-profit corporations as subcontractors, unfunded collaborators, contributors, or GOALI partners.

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.4 of the Grant Proposal Guide provides additional information on

collaborative proposals.

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

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

The following information supplements the guidelines and requirements in the NSF Grant Proposal Guide (GPG) and 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 Frontiers Project proposal title would be "*CPS: Frontiers: 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 Synergy Project would be "*CPS: Synergy: Collaborative Research: Title.*" Proposals from PIs in institutions that have RUI (Research in Undergraduate Institutions) eligibility should also include "RUI" followed by a colon before the project title, for example, "*CPS: Synergy: RUI: Title.*" Similarly, GOALI (Grant Opportunities for Academic Liaison with Industry) proposals should include "GOALI" followed by a colon as the last identifier before the project title.

Project Summary: In addition to clearly addressing the intellectual merit and broader impacts, the project summary should include a prioritized list of keywords and CPS Research Target Areas that characterize the project, to be entered into the Overview section. The project summary should explicitly identify how the CPS Research Target Area(s) are addressed in the proposed project (i.e., *Science of Cyber-Physical Systems; Technology for Cyber-Physical Systems;* and/or *Engineering of Cyber-Physical Systems*). Proposals to address a next-generation CPS application in conjunction with research in one or more of the three target areas should also specify the target application(s) in the Project Summary.

Project Description: Proposals should explicitly identify the CPS Research Target Area(s) being addressed in the proposed project in the Project Description. Proposals to address a next-generation CPS application in conjunction with research in one or more of the three target areas should also specify the target application(s) in the Project Description.

All proposals are expected to:

- describe how the project goals and research and education outcomes will contribute to the realization of the CPS program goal and vision;
- explain their specific contribution to CPS science and technology;
- specify how the project research will contribute to one or more of the three CPS Research Target Areas;
- explain how the project research fits the Program Description for the type of Proposal (*Breakthrough*, *Synergy*, or *Frontiers*);
- present a plan to integrate research outcomes into education and more broadly advance education in CPS;
- describe the roles, responsibilities, and expertise of the team members, how they cover the set of skills needed to realize the project goals and how their interactions will contribute to integration across core CPS disciplinary areas;
- include a plan for validation of the research by experimentation and prototyping;
- provide plans for disseminating the research and education outcomes in a manner that enables the CPS research community and helps scientists and engineers to use the results in ways that go beyond traditional academic publications; and
- if the proposal involves a collaboration spanning multiple institutions, it must provide a compelling rationale for the multi-institutional structure of the project and an explanation of how effective collaboration will be assured.

In addition, for projects of more than 3 years, the validation plan must include experimentation on an actual cyber-physical system.

For Synergy and Frontiers proposals, the page limit has been increased to 20 pages.

Supplementary Documents:

All projects are strongly encouraged to share results, including software, test beds, and other artifacts, with the CPS research community through the CPS Virtual Organization (VO). Plans should be described in the Data Management Plan. Frontiers project proposals are required to include a plan for such sharing, as well as transition to practice, involving potential end users and stakeholders.

Letters of commitment provided as Supplementary Documents should detail the level of commitment to the project.

For institutions that have RUI eligibility, proposals should also include a Research in Undergraduate Institutions (RUI) Impact Statement and Certification of RUI Eligibility in the Supplementary Documents section (See Chapter II.C.2j of the GPG for additional information).

Additional Supplementary Documents for Breakthrough projects:

Breakthrough project proposals must have a persuasive argument for why the research, if successful, would significantly change the field of cyber-physical systems. This description must be uploaded into the Supplementary Documents section in Fastlane or Grants.gov. It shall not exceed 1 page.

Additional Supplementary Documents for Frontiers projects:

Education and Outreach Plan: Frontiers project proposals must have an Education and Outreach Plan. This plan is separate from the Project Description and must be uploaded into the Supplementary Documents section in Fastlane or Grants.gov. It shall not exceed 3 pages. The plan should describe educational approaches that overcome traditional stove-piped curricula and better prepare students for careers in cyber-physical systems practice and research. The plan should also address the goals of achieving impact on educational practices beyond the participating institutions, and expanding the CPS community. The CPS program is interested in ideas that address the under-representation of women, minorities, and persons with disabilities, and stimulate interest in cyber-physical systems at the K-12 level and in the public at large.

Management Plan: Frontiers project proposals must include a plan describing the organizational structure and management strategy of the project as a whole. It shall not exceed 3 pages. It should explain how collaboration among individuals and across

organizations will be assured, and how progress toward the project objectives will be tracked. The plan should enumerate the roles of the PIs and senior researchers in the project and explain how the activities of each will contribute to the project objectives. It should describe the mechanisms that will be used throughout the duration of the project to coordinate and integrate the activities of the participants, and include a time-line for these coordination activities. It should identify a single individual who will be responsible for executing the management plan and the amount of the budget that will be allocated for project administration. The Management Plan should include a kick-off meeting of all participants in coordination with the NSF. Proposals involving collaborations spanning multiple institutions must provide a compelling rationale for the multi-institutional structure of the project and a single Management Plan. Note: this management plan is in addition to the data management plan required for all NSF proposals.

Note that the GPG contains additional guidance and requirements for Supplementary Documents.

B. Budgetary Information

Cost Sharing: Inclusion of voluntary committed cost sharing is prohibited

Budget Preparation Instructions:

Budgets for all projects must include funding for one or more 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

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

  January 14, 2013 - January 29, 2013

  January 14 - January 29, Annually Thereafter

D. FastLane / Grants.gov Requirements

- 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. The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

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

- For Proposals Submitted Via Grants.gov:

  Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. Comprehensive information about using Grants.gov is available on the Grants.gov Applicant Resources webpage: http://www07.grants.gov/applicants/app_help_reso.jsp. 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. 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

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://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

Empowering the Nation Through Discovery and Innovation: NSF Strategic Plan for Fiscal Years (FY) 2011-2016. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

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

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

A. Merit Review Principles and Criteria

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

All proposals will be evaluated with respect to their emphasis on holistic, integrative approaches to cyber-physical systems that are applicable to more than one application domain and the extent to which they address specific CPS Research Target Area(s). Frontiers project proposals will also be evaluated on the strength of their Education and Outreach Plan and Management Plan.

B. Review and Selection Process

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

Reviewers will be asked to 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

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 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. 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.

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

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

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

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

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

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:

- Helen Gill, CISE Point of Contact for the CPS program, 1175, telephone: (703) 292-7834, email: hgill@nsf.gov
- David Corman, CISE Point of Contact for the CPS program, 1175, telephone: (703) 292-8950, email: dcorman@nsf.gov
- Radhakisan Baheti, ENG Point of Contact for the CPS program, 525, telephone: (703) 292-8339, email: rbaheti@nsf.gov
- Theodore P. Baker, Program Director, CISE/CNS, 1175, telephone: (703) 292-8608, email: tbaker@nsf.gov
- Bruce Kramer, Program Director, ENG/CMMI, 545S, telephone: (703) 292-5348, email: bkramer@nsf.gov
- Ralph Wachter, Program Director, CISE/CNS, 1175, telephone: (703) 292-8950, email: rwachter@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, "My NSF" 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. "My NSF" 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

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

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

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

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

regarding preparation of these types of proposals.

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

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

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

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

- Location: 4201 Wilson Blvd. Arlington, VA 22230
- For General Information (NSF Information Center): (703) 292-5111
- TDD (for the hearing-impaired): (703) 292-5090
- To Order Publications or Forms:

  Send an e-mail to: nsfpubs@nsf.gov

  or telephone: (703) 292-7827
- To Locate NSF Employees: (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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

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

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