

Cyber-Physical Systems (CPS)

PROGRAM SOLICITATION

NSF 14-542

REPLACES DOCUMENT(S):

NSF 13-502



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
Division of Advanced Cyberinfrastructure

Directorate for Engineering
Division of Electrical, Communications and Cyber Systems
Division of Civil, Mechanical and Manufacturing Innovation
Division of Chemical, Bioengineering, Environmental, and Transport Systems



Department of Homeland Security, Science & Technology Directorate



U.S. Department of Transportation, Federal Highway Administration

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

May 19, 2014 - June 02, 2014

December 01, 2014 - December 15, 2014

December 1 - December 15, Annually Thereafter

IMPORTANT INFORMATION AND REVISION NOTES

The Cyber-Physical Systems (CPS) program solicitation has been revised for the FY 2014 competition, and prospective Principal Investigators are encouraged to read the solicitation carefully. Among the changes are the following:

- The U.S. Department of Homeland (DHS) Security Science and Technology Directorate (S&T), U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) and, through FHWA, U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO) have joined the program.
- A new supplemental option on "Transition to Practice" (TTP) is being offered.
- A new emphasis on the potential utilization of testbeds for CPS research has been added.
- New requirements for Supplementary Documents for Breakthrough and Frontier proposals have been introduced.
- A requirement for a list of collaborators for all members of the project team, to be submitted as a Supplementary Document, has been added.

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 seamless integration of computational algorithms and physical components. Advances in CPS will enable capability, adaptability, scalability, resiliency, safety, security, and usability that will far exceed the simple embedded systems of today. CPS technology will transform the way people interact with engineered systems -- just as the Internet has transformed the way people interact with information. New smart CPS will drive innovation and competition in sectors such as agriculture, energy, transportation, building design and automation, healthcare, and manufacturing.

The December 2010 report of the President's Council of Advisors on Science and Technology (PCAST) titled

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 such as the ones noted above. These challenges and technology gaps are further described in a *CPS Vision Statement* published in 2012 by the Federal Networking and Information Technology Research and Development (NITRD) Program's CPS Senior Steering Group.

Tremendous progress has been made in advancing CPS technology over the last five years. We have explored foundational technologies that have spanned an ever-growing set of application domains, enabling breakthrough achievements in many of these fields. At the same time, the demand for innovation in these domains continues to grow, and is driving the need to accelerate fundamental research to keep pace.

Despite significant inroads into CPS technology in recent years, 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, minor events that trip the current electric power grid -- an ad hoc system -- can escalate with surprising speed into widespread power failures. This scenario 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 thus significant and far-reaching. New relationships between the cyber and physical components require new architectural models that redefine form and function. They integrate 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, temporally, or hierarchically distributed in configurations that may rapidly change. With the greater autonomy and cooperation possible with CPS, greater assurances of safety, security, scalability, and reliability are demanded, placing a high premium on open interfaces, modularity, interoperability, and verification.

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 seeks 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 testbeds.

In 2014, NSF is working closely with multiple agencies of the federal government, including the U.S. Department of Homeland (DHS) Security Science and Technology Directorate (S&T), U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) and, through FHWA, U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO), to identify basic research needs in CPS common across multiple application domains, along with opportunities for accelerated transition to practice.

Three types of research and education projects -- differing in scope and goals -- will be considered through this solicitation:

- **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.
- **Frontier** 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.

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.

- David Corman, Program Director, CISE/CNS, 1175, telephone: (703) 292-8754, email: dcorman@nsf.gov
- Radhakisan Baheti, Program Director, ENG/ECCS, 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, 545, telephone: (703) 292-5348, email: bkramer@nsf.gov
- Bruce Hamilton, Program Director, ENG/CBET, 565, telephone: (703) 292-7066, email: bhamilto@nsf.gov
- Frank Olken, Program Director, CISE/IIS, 1125, telephone: (703) 292-4767, email: folken@nsf.gov
- Phillip Regalia, Program Director, CISE/CCF, 1115, telephone: (703) 292-8910, email: pregalia@nsf.gov
- Sylvia Spengler, Program Director, CISE/IIS, 1125, telephone: (703) 292-8930, email: sspengle@nsf.gov
- Kevin Thompson, Program Director, CISE/ACI, 1145, telephone: (703) 292-4220, email: kthomps@nsf.gov
- Ralph Wachter, Program Director, CISE/CNS, 1175, telephone: (703) 292-8950, email: rwachter@nsf.gov
- Daniel Massey, Program Director, DHS S&T, telephone: 202-254-0908, email: daniel.massey@hq.dhs.gov
- David Kuehn, Program Manager, DOT/FHWA, telephone: (202) 493-3414, email: david.kuehn@dot.gov
- Kevin Dopart, Program Director, DOT/ITS JPO, telephone: 202-366-8034, email: kevin.dopart@dot.gov

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

- 20.200 --- Highway Research and Development Program
- 47.041 --- Engineering
- 47.070 --- Computer and Information Science and Engineering
- 97.065 --- Homeland Security Advanced Research Projects Agency

Award Information

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

Estimated Number of Awards: 20 to 32

Approximately 10 Breakthrough projects, 20 Synergy projects, and 2 Frontier projects are anticipated in FY 14.

Anticipated Funding Amount: \$35,000,000 in FY 14, subject to the availability of funds and receipt of sufficient meritorious proposals.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

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

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An individual can participate as PI, co-PI, or Senior Personnel on **no more than two proposals** submitted in response to this solicitation.

These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently. 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). **No exceptions will be made.**

Additionally, proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by other NSF, DHS or DOT programs. Duplicate or substantially similar proposals will be returned without review, including those substantially similar to previously declined proposals without revisions to address concerns raised by reviewers.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

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

B. Budgetary Information

- **Cost Sharing Requirements:** Inclusion of voluntary committed cost sharing is prohibited.
- **Indirect Cost (F&A) Limitations:** Not Applicable
- **Other Budgetary Limitations:** Not Applicable

C. Due Dates

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

May 19, 2014 - June 02, 2014

December 01, 2014 - December 15, 2014

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: Additional reporting requirements apply. Please see the full text of this solicitation for further information.

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I. INTRODUCTION

Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the seamless integration of computational algorithms and physical components. Advances in CPS will enable capability, adaptability, scalability, resiliency, safety, security, and usability that will far exceed the simple embedded systems of today. CPS technology will transform the way people interact with engineered systems -- just as the Internet has transformed the way people interact with information. New smart CPS will drive innovation and competition in sectors such as agriculture, energy, transportation, building design and automation, healthcare, and manufacturing.

Tremendous progress has been made in advancing CPS technology over the past five years. We have explored foundational technologies that have spanned an ever-growing set of application domains, enabling breakthrough achievements in many disparate fields such as those noted above. At the same time, the demand for innovation in these domains continues to grow, and is driving the need to accelerate fundamental research to keep pace.

Despite significant inroads into CPS technology in recent years, 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, minor events that trip the current electric power grid -- an ad hoc system -- can escalate with surprising speed into widespread power failures. This scenario 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 thus significant and far-reaching. New relationships between the cyber and physical components require new architectural models that redefine form and function. They integrate 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, temporally, or hierarchically distributed in configurations that may rapidly change. With the greater autonomy and cooperation possible with CPS, greater assurances of safety, security, scalability, and reliability are demanded, placing a high premium on open interfaces, modularity, interoperability, and verification.

The CPS program seeks to develop the core system science needed to enable development of complex CPS upon which people can depend with high confidence. The program also aims to foster a research community committed to advancing research and education in CPS and to transitioning applicable 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 scientific foundations and engineering principles must overcome challenges that are ubiquitous and fundamental for this class of systems. For example, one CPS consideration is 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 a given system and its environment. Another consideration is that 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.

Toward these considerations, new concepts need to be devised. Foundations and engineering principles must support a unifying model that enables CPS that are both open and modular. Adequate solutions to these problems will require an integrated perspective of real-time computing, communications, dynamics, and control.

The CPS program therefore:

- takes a coordinated approach that balances theory with experimentation, and systematic advances with revolutionary breakthroughs;
- seeks cross-disciplinary collaborative research that will lead to new fundamental insights;
- encourages empirical validation of new concepts through research prototypes, ranging from component devices to entire systems; and
- aims to identify promising innovations that have the potential of immediate practical applications, supporting transitioning such innovations to practice.

The program also recognizes that CPS innovation can be fostered by the presence of open, scalable, and extensible testbeds that enable early research concepts to be explored in a realistic environment.

In 2014, NSF is working closely with multiple agencies of the federal government, including the U.S. Department of Homeland (DHS) Security Science and Technology Directorate (S&T), U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA) and, through FHWA, U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO), to identify basic research needs in CPS common across multiple application domains, along with opportunities for accelerated transition to practice.

To help achieve these aims, this CPS program solicitation aims to:

- Pursue fundamental research in CPS that spans multiple domains;
- Identify early-stage CPS research that addresses important needs of mission agencies as described in II.C, and has potential for accelerated maturation, demonstration, and transition to practice; and
- Encourage research utilization of both academic and industry testbeds that can integrate research components.

To the last point above, effective use of testbeds can spur innovations and accelerate research by providing scalable and open environments for experimentation. If applicable, researchers should consider using testbeds that include virtual simulation environments for early experimentation, higher fidelity hardware-in-the-loop environments and live platforms. The program strongly encourages proposers to include in their proposals how their research may take advantage of such testbeds as means for experimental validation and maturation in realistic environments.

II.A Research Areas

This solicitation seeks to address foundational issues that are central across CPS applications, including, but not limited to, the following:

- *System Design* -- How do we design CPS to be safe, secure, and resilient in a variety of unanticipated and rapidly evolving environments and disturbances? How do we integrate privacy and security into CPS design?
- *System Verification* -- How do we develop effective metrics and methods to rapidly verify and certify very large and complex CPS? What technologies enable incremental certification? How can we preserve safety yet dramatically reduce the "test space" when it comes to manned, unmanned, and mixed authority systems spanning a variety of disciplines?
- *Real-time Control and Adaptation* -- How do we achieve real-time dynamic control and behavior adaptation in a diversity of environments such as clouds, as well as in network-challenged spaces? How can CPS leverage "big data" in real-time control?
- *Manufacturing* -- How can communication, computation, and control be harnessed to provide expanded and effective access to means of conceiving of new products, reducing product concepts to realizable designs, and producing integrated software-hardware systems at a pace far exceeding today's timelines?

While the CPS program welcomes proposals that address research issues across a wide range of domains in CPS, a proposal must address at least one of the following three "research target areas" as described below: Science of Cyber-Physical Systems; Technology for Cyber-Physical Systems; and/or Engineering of Cyber-Physical Systems.

II.A.1 Science of Cyber-Physical Systems: CPS must move beyond the classical fundamental models of computation and physics. 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.

II.A.2 Technology for Cyber-Physical Systems: New design, analysis, and verification tools that embody the scientific principles of CPS and incorporate measurement, dynamics, and control are needed. These tools should offer important perspectives into behaviors and interactions of CPS. 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 to maintain certification as a system evolves.

II.A.3 Engineering of Cyber-Physical Systems: CPS opens a new opportunity to rethink the principles and methods of systems engineering that are built on the foundations of CPS science and technology. Attention should be given to system architectures,

designs, and integrations as well as the exploration of design spaces that will produce certifiably dependable systems. New engineering principles are needed to systematize design for the growing numbers of CPS that involve adaptation and autonomy. All advances should be assessed by appropriate benchmarks. The engineering processes must also support certification and maintenance of certification over system lifecycles.

Across all these research target areas, 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 above. 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 address societal challenges. Challenge applications can range from highly focused inventions enabled by CPS technology to revolutionary approaches for next-generation infrastructures. The program encourages projects that address concerns shared by other federal agencies such as agriculture, energy, transportation, health, and national security. The program especially welcomes projects that address renewable energy, advanced manufacturing, and automation for vehicle and highway safety, reliability, and efficiency.

The CPS program also has interest in proposals that demonstrate the development of foundational capabilities that can be integrated with successively higher fidelity testbeds including actual CPS. Proposals should pursue principled experimentation, prototyping, and validation activities to show viability of the proposed research. Research programs that include a transformative component as well as transition to practice component (as a second phase of the proposed activities) are encouraged -- especially in focus areas of relevance to the federal mission agencies mentioned above. Experimentation on an actual cyber-physical system is required for projects of greater than three years.

II.B Types of Proposals

The following three types of research and education proposals that differ in scope and goals 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, communications, 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. A successful Breakthrough project 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 that persuasively reasons why the research to be undertaken, if successful, would significantly change the field of cyber-physical systems. This statement must be submitted as a document under Supplementary Documentation. Breakthrough proposals may be up to \$500,000 in total budget, with durations of up to three years.

Synergy Projects: The proposed research should demonstrate innovation at the intersection of multiple disciplines. The research must have a clear goal that reflects a shared perspective, crossing the disciplines and achieving integration. The proposal must explain clearly the synergy that will be achieved by the collaboration. Synergy proposals must be between \$500,001 and \$1,000,000 in total budget, with durations of three to four years.

Frontier 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 testbed. There must be a plan for sharing results, including testbeds and artifacts, with the CPS research community through the [CPS Virtual Organization \(CPS-VO\)](#). Frontier proposals may additionally include a Transition to Practice (TTP) Option, as specified in Section II.D, that considers maturation of technologies for broader application and involves potential end users and stakeholders. Frontier proposals may be from \$1,000,001 to \$7,000,000 in total budget, with durations of four to five years.

II.B.1 Other Funding Opportunities: The CPS program notes the Computing Research Infrastructure (CRI; see [NSF 13-585](#)) and Major Research Instrumentation (MRI; see [NSF 13-517](#)) programs as potential sources of funding for community infrastructure and experimental testbeds for CPS research.

II.C Sponsoring Agency Mission-Specific Research

NSF welcomes proposals addressing any of the fundamental CPS research areas described in section II.A above. In addition, through this solicitation, multiple federal agencies are interested in addressing CPS basic research needs of relevance to their missions, along with opportunities for accelerated transition to practice. These interests are described below.

II.C.1 U.S. Department of Homeland Security Science and Technology Directorate (DHS S&T) Homeland Security Advanced Research Project Agency (HSARPA)

Within the U.S. Department of Homeland Security Science and Technology Directorate (DHS S&T), the Advanced Research Project Agency (HSARPA) encourages research and development in cybersecurity to enhance the resilience of critical information infrastructure. HSARPA seeks to develop and transition new technologies, tools, and techniques to secure systems, networks, and infrastructure. Its research interests span a broad range of technology maturity levels ranging from foundational research in cybersecurity technology, to development and transition to practice.

HSARPA has particular interests in security technologies relevant to cyber-physical systems. The NITRD CPS Senior Steering Group's 2012 [CPS Vision Statement](#), which notes CPS research gaps, identifies drivers and technologies for CPS. CPS related to transportation, emergency response, energy, and healthcare are considered especially relevant for HSARPA. Relevant technologies include cybersecurity approaches for guarding against malicious attacks on CPS as well as diagnostics and prognostics that aim to identify, predict, and prevent or recover from faults. Validation, verification, and certification that speed up design cycles while ensuring high confidence in system safety and functionality also align well with HSARPA interests.

More information about relevant DHS S&T cybersecurity technology interests can be found on the following website: <http://www.dhs.gov/csd-program-areas>.

II.C.2 U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA)

The Federal Highway Administration (FHWA), in coordination with other agencies in the Department of Transportation (DOT) and elsewhere, has been researching connected highway and vehicle systems to improve the safety, mobility, and efficiency of the nation's highways. Under its [Exploratory Advanced Research \(EAR\) program](#), FHWA is funding research to leapfrog current technological approaches for linking infrastructure with future vehicle and personal mobility technology to improve safety and mobility. Specific areas of interest within the EAR program include enabling technology for positioning, navigation, time synchronization, sensor integration, and improved situational awareness, as well as new system concepts for vehicle platooning, speed management, intersection management, and vehicle merging. (For more information about the EAR Program and results relating to connected vehicles, see the following website: <http://www.fhwa.dot.gov/advancedresearch/>.)

All of these topics depend on the tight coupling of physical and computational system elements and will benefit from foundational

research in CPS spanning multiple disciplines and domains. Based on recent research results, anticipated results from continued research investments, and ongoing scanning of scientific and engineering advances, the FHWA EAR program has identified two areas where a coordinating investment with NSF would best advance both the fundamental science of CPS and speed the application of scientific advances into the highway industry: **enabling technology** and **scaling cyber-physical highway systems**. FHWA particularly has interest in foundational technologies that can accelerate innovation, reduce cost, and lower risk of technology adoption.

Enabling Technology:

FHWA has interest in research and development of new enabling technology that provides improved safety, mobility, and energy conservation in the development and operation of the highway system. Enabling technologies for highway transportation must be scalable, reliable, adaptable, and secure while also being cost-effective. While initial deployment of new technologies may begin in specific corridors, the technologies need to be scalable, reliable, affordable, and adaptable to enable nationwide deployment as well as operation over periods of 30 or more years.

Scaling Cyber-Physical Highway Systems:

FHWA is interested in new research methods to test connected vehicle and highway systems at larger scales. This may include new simulation methods, hardware-in-the-loop or hybrid physical and simulated environments, methods for connecting and exploiting existing smaller scale testbeds, and/or methods for safe and effective real world or "living laboratory" testing. More importantly, new methods are needed to test the safety and efficacy of large-scale, complex systems. Such methods need to account for a combination of legacy equipment and new systems. While people may update mobile devices every two years, the average age of private motor vehicles is now over 10 years. Roadway signals, infrastructure sensors, truck trailers, and other elements of the highway system have even longer lifecycles before being replaced. Accordingly, new systems need to work with existing equipment while anticipating future technologies.

FHWA anticipates research teams may wish to take advantage of expertise, facilities, and equipment located at the [Saxton Transportation Operations Laboratory](#) or the [Human Factors Laboratory](#) at the Turner Fairbank Highway Research Center (TFHRC) in McLean, Virginia. Research Teams may contact the Federal laboratory manager to discuss possible access to laboratory facilities that could be included in a proposal. Discussions with, and inclusion of, research conducted at the Saxton Transportation Operations Laboratory does not guarantee acceptance of the proposal. Proposals that include experiments at TFHRC do not need to include FHWA associated costs, which will be funded separately.

FHWA interests extend further through a partnership with the DOT's **Intelligent Transportation Systems (ITS) Joint Program Office (JPO)**, which seeks CPS research in the area of **connected automated vehicles**.

Connected Automated Vehicles:

The ITS JPO is planning research to better understand how to blend Connected Vehicle (CV) technology and autonomous vehicle systems. CV technology has the potential to inform vehicles and drivers about the dynamics, movements, and intents of other vehicles in their surroundings. The ITS JPO is coordinating research activities across the DOT, exploring the role of CPS applications across multiple transportation modes and networks. CPS technology research challenges include: CPS data acquisition, quality assurance and integration; data and information analytics; and decision making, including electronic control systems. There is also a need to detect, locate, and remediate degraded components of connected automated vehicle systems. CPS technology challenges are focused on understanding the development and integration of the essential building blocks and capabilities needed to allow automated vehicle systems to perform safely and effectively on public roadways using functionality not traditionally available to autonomous sensors alone.

CPS research proposals should consider the potential use of [ITS JPO Connected Vehicle \(CV\) Testbeds](#). The CV testbed and associated interoperable testbed environments constitute real-world, operational testbeds. They provide supporting vehicles, infrastructure, and equipment to serve the needs of public- and private-sector testing and certification activities, including CPS research. The testbeds are enablers to accelerating innovative research and transition to practice, as they establish multiple locations as part of one connected system that can support continued research, testing, and demonstration of connected vehicle concepts, standards, applications, and innovative products. Test environments may also serve as precursors or foundations for state and local deployments using CV technologies.

For more information, see the DOT [program plan for automation](#), [CV Program](#), and [CV testbeds](#).

All sponsor-targeted proposals:

Those proposals that are targeting a specific agency sponsorship should indicate so in the last line of the last box of the Project Summary, e.g., "Requested funding agency:" followed by that agency's abbreviated name, i.e., "NSF," "DHS," or "DOT," but only if the proposers have previously communicated with a program officer from that agency and received permission or instruction to do so. Those not so designated will be considered for funding by all of the joint sponsoring agencies.

II.D Transition to Practice (TTP) Option

Proposals for Breakthrough, Synergy, or Frontier projects may include a Transition to Practice (TTP) option. Proposed activities under the TTP option MUST NOT be described in the project description, and instead MUST be described in a supplemental document of no more than five pages. The TTP option is meant to support the leveraging of proposed research activities and ideas whose outcomes at the end of the award are capable of being implemented, matured, applied, experimentally useable, or demonstrated as a useable capability. This option should describe how successful research results are to be further developed, matured and experimentally deployed in organizations or industries, including in networks and end systems. Any software developed in this program area is required to be released under an open source license listed by the Open Source Initiative (<http://www.opensource.org/>) (this requirement is specific to the TTP option supplement). Proposals with a TTP option may exceed the above-stated maxima by up to \$167,000 for Breakthrough projects, \$400,000 for Synergy projects, and \$1,000,000 for Frontier projects.

(Note: The TTP option is an optional component, above and beyond the requirement for experimentation on an actual cyber-physical system for projects of greater than or equal to three years duration).

Proposals submitted with a TTP option will be evaluated with careful attention to the following:

- The expected impact on the deployed environment described in the supplemental document;
- The extent to which the value of the proposed CPS research and development is described in the context of a needed capability and potential impact;
- The feasibility, utility, and interoperability of the capability in its proposed operational role;
- A plan that addresses in its goals and milestones the demonstration and evaluation of a working system in the target

- environment;
- Tangible metrics described to evaluate the success of the capabilities developed, and the steps necessary to take the system from prototype status to production use; and
- The appropriateness of the budget for the option. The supplemental document should explain how the additional budget will be used to execute the option.

If you submit a Transition to Practice (TTP) option, the title should begin with the acronym that indicates the relevant perspectives followed by a colon, then "TTP Option" followed by a colon, then the project class followed by a colon, and then the title. For example, a CPS Frontier project with the TTP option should have a title of the form **CPS: TTP Option: Frontiers: Title**.

II.E CPS PI Meetings

The CPS program is aiming to build a new research and education community. In this spirit, the program plans to host PI meetings every year with participation from all funded projects and other representatives from the research community, government and industry. The program also sponsors the [CPS Virtual Organization \(CPS-VO\)](#), a broad community of interest for CPS researchers, developers, and educators. Principal investigators are expected to participate in the PI meetings, and are encouraged to use the CPS-VO to coordinate activities and artifacts along with research results.

For all awards, one or more project representatives (PI/co-PI/senior researcher, or NSF-approved replacement) must attend EVERY PI meeting held throughout the duration of the grant.

II.F Embedded REU Supplements

The Research Experiences for Undergraduates (REU) solicitation ([NSF 13-542](#)) gives instructions for embedding a request for a REU Supplement in a proposal. Proposers are invited to embed a request for a REU Supplement in the typical amount for one year only according to normal CISE guidelines (detailed below). The amounts of the REU Supplements do not count against the budget limitations described in this solicitation.

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

As a guide for budget development, CISE REU supplement support averages about \$8,000 per student per year; this guideline is neither a floor nor a ceiling. As described in the solicitation, indirect costs (F&A) are not allowed on Participant Support Costs in REU Site or REU Supplement budgets. Note that the REU solicitation's longstanding "administrative allowance" of 25% of the participant support stipend amount in lieu of indirect costs has been discontinued.

REU stipend support is one way to retain talented students in undergraduate education, while providing meaningful research experiences. The participation of students from groups underrepresented in computing -- underrepresented minorities, women and persons with disabilities -- is strongly encouraged. Underrepresented minorities include Blacks, Hispanics, Native Americans, and Native Pacific Islanders. Other factors influencing the funding decision regarding the supplement include the number of REU requests submitted by any one principal investigator across all of her/his CISE grants.

Investigators are encouraged to refer to the program solicitation Research Experiences for Undergraduates (REU): Sites and Supplements ([NSF 13-542](#)) for more information concerning submission requirements. For questions, contact one of the Cognizant Program Officers listed in this solicitation.

III. AWARD INFORMATION

All awards made under this solicitation by NSF, DHS, and DOT will be as grants or cooperative agreements or other contract vehicles as determined by the supporting agency.

Upon conclusion of the review process, meritorious research proposals may be recommended for funding by one of the participating agencies, determined at the option of the agencies, not the proposer. Subsequent grant administration procedures will be in accordance with the individual policies of the awarding agency, and may require submission of a revised proposal that meets the administrative requirements of the funding agency. (See section V.B. for additional information on agency-specific processes).

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

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

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An individual can participate as PI, co-PI, or Senior Personnel on **no more than two proposals** submitted in response to this solicitation.

These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently. 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). **No exceptions will be made.**

Additionally, proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by other NSF, DHS or DOT programs. Duplicate or substantially similar proposals will be returned without review, including those substantially similar to previously declined proposals without revisions to address concerns raised by reviewers.

Additional Eligibility Info:

The CPS program encourages applications from groups eligible to compete as Research in Undergraduate Institutions (RUI; see [NSF 00-144](#)) or Grants Opportunities for Academic Liaison with Industry (GOALI; see [NSF 12-513](#)) under the CPS program deadlines.

In addition, 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.

Please note that per guidance in the GPG, the Project Description must contain, as a separate section within the narrative, a discussion of the broader impacts of the proposed activities. Unless otherwise specified in this solicitation, you can decide where to include this section within the Project Description.

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 CPS Frontier project proposal title would be **CPS: Frontier: 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 that include a Transition to Practice (TTP) option should include "TTP Option" followed by a colon immediately after identifying as CPS. For example, a CPS Frontier project with the TTP option should have a title of the form **CPS: TTP Option: Frontiers: 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: At the top of the Overview text box, enter the title of the CPS project, the name of the lead PI, and the name of the lead institution. Provide an overview description of the CPS project, including the intellectual merit and broader impacts of the proposed work. This description should explicitly identify how the CPS research target area(s) described in section II.A above (i.e., Science of Cyber-Physical Systems; Technology for Cyber-Physical Systems; and/or Engineering of Cyber-Physical Systems) are addressed in the proposed project. Proposals that seek 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. At the end, include a prioritized list of keywords and CPS research target area(s) that characterize the project. In separate statements, provide a summary of the intellectual merit of the proposed project in the "intellectual merit" box, and broader impacts in the "broader impacts" box. Those proposals that are targeting a specific agency sponsorship should indicate so in the last line of the last box, e.g., "Requested funding agency:" followed by that agency's abbreviated name, i.e., "NSF," "DHS," or "DOT," but only if the proposers have previously communicated with a program officer from that agency and received permission or instruction to do so. Those not so designated will be considered for funding by all of the joint sponsoring agencies.

Project Description: Describe the research and education activities to be undertaken in **up to 15 pages for Breakthrough and Synergy proposals and up to 20 pages for Frontier proposals.**

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 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 *Frontier*);
- 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, 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 three years, the validation plan must include experimentation on an actual cyber-physical system.

Supplementary Documents: In the Supplementary Documents section, upload the following:

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

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

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

(2) *A list of Collaborators* (Note: In collaborative proposals, only the lead institution should provide this information):

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

1. Mary Smith; XYZ University
2. John Jones; University of PQR
3. Jane Brown; XYZ University
4. Bob Adams; ABC Inc.
5. Mary White; Welldone Institution
6. Tim Green; ZZZ University

(3) *Justification for Breakthrough Proposals:*

Proposals for Breakthrough projects are required to have a statement of up to one page that persuasively reasons why the research to be undertaken, if successful, would significantly change the field of cyber-physical systems. **Proposals that include justifications exceeding one page in length will be returned without review.**

(4) *Collaboration Plans for Breakthrough and Synergy (if applicable) as well as Frontier Proposals:*

Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, all Breakthrough and Synergy proposals that include more than one investigator and all Frontier proposals must include a Collaboration Plan of up to 2 pages. The length and degree of detail provided in the

Collaboration Plan should be commensurate with the complexity of the proposed project. Where appropriate, the Collaboration Plan might include: 1) the specific roles of the project participants in all organizations involved; 2) information on how the project will be managed across all the investigators, institutions, and/or disciplines; 3) identification of the specific coordination mechanisms that will enable cross-investigator, cross-institution, and/or cross-discipline scientific integration (e.g., yearly workshops, graduate student exchange, project meetings at conferences, use of the grid for videoconferences, software repositories, etc.), and 4) specific references to the budget line items that support collaboration and coordination mechanisms.

In the case of Frontier projects, the collaboration plan should also: 1) identify a single individual who will be responsible for executing the collaboration plan and the amount of the budget that will be allocated for project administration; and 2) include a kick-off meeting of all participants in coordination with the NSF.

If a Frontier proposal, or a Breakthrough or Synergy proposal with more than one investigator, does not include a Collaboration Plan of up to 2 pages, that proposal will be returned without review.

(5) Education and Outreach Plan for Frontier Proposals

All Frontier projects must include an Education and Outreach Plan of up to three pages. This plan, separate from the Project Description, should describe educational approaches that overcome traditional 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 underrepresentation of women, minorities, and persons with disabilities in CPS science, technology, and engineering, and that stimulate interest in cyber-physical systems at the K-12 level and in the public at large.

If a Frontier proposal does not include an Education and Outreach Plan of up to 3 pages, that proposal will be returned without review.

(6) Transition to Practice (TTP) Option Proposals:

Projects may include a Transition to Practice (TTP) option. Proposals submitted with a TTP option must include a supplemental document of up to five pages in order for the option to be considered for funding. This document should describe how successful proposed research results are to be further developed, matured, and experimentally deployed in organizations, networks and end systems. It should also include an option budget that indicates what additional funds would be needed to carry out the TTP option. This budget for the TTP option may be no larger than \$167,000 for Breakthrough projects, no larger than \$400,000 for Synergy projects, and no larger than \$1,000,000 for Frontier projects.

Note that the budget for the TTP option must be specified separately within the five-page supplement. In addition, it must also be incorporated into the budget sheets for the overall proposal.

(7) Postdoctoral Researcher Mentoring Plan (if applicable):

Each proposal that requests funding to support postdoctoral researchers must include, as a supplementary document, a description of the mentoring activities that will be provided for such individuals. In no more than one page, the mentoring plan must describe the mentoring that will be provided to all postdoctoral researchers supported by the project, irrespective of whether they reside at the submitting organization, any subawardee organization, or at any organization participating in a simultaneously submitted collaborative project. Please be advised that if required, FastLane will not permit submission of a proposal that is missing a [Postdoctoral Researcher Mentoring Plan](#). See [Chapter II.C.2.j](#) of the GPG for further information about the implementation of this requirement. **Proposals that include Postdoctoral Mentoring Plans exceeding one page in length will be returned without review.**

(8) Data Management Plan (required):

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

See [Grant Proposal Guide \(GPG\) Chapter II.C.2.j](#) for full policy implementation.

For additional information see <http://www.nsf.gov/bfa/dias/policy/dmp.jsp>.

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

In the case of CPS, all projects are strongly encouraged to share results, including software, testbeds, and other artifacts, with the CPS research community through the [CPS Virtual Organization \(CPS-VO\)](#). Plans for sharing should be described in the Data Management Plan. Frontier project proposals are required to include a plan for such sharing, along with transition to practice, involving potential end users and stakeholders.

Proposals that include Data Management Plans exceeding two pages in length will be returned without review.

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 each CPS PI Meeting during the proposed lifetime of the award (per Section II.E above). For budget preparation purposes, PIs should assume these meetings will be held in the fall of each year in the Washington, DC, area.

C. Due Dates

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

May 19, 2014 - June 02, 2014

December 01, 2014 - December 15, 2014

December 1 - December 15, Annually Thereafter

D. FastLane/Grants.gov Requirements

For Proposals Submitted Via FastLane:

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

For Proposals Submitted Via Grants.gov:

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

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

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

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

Proposals received by NSF are assigned to the appropriate NSF program for acknowledgement and, if they meet NSF requirements, for review. All proposals are carefully reviewed by a scientist, engineer, or educator serving as an NSF Program Officer, and usually by three to ten other persons outside NSF either as *ad hoc* reviewers, panelists, or both, who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with oversight of the review process. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal and/or persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Submission of such names, however, is optional. Care is taken to ensure that reviewers have no conflicts of interest with the proposal. In addition, Program Officers may obtain comments from site visits before recommending final action on proposals. Senior NSF staff further review recommendations for awards. A flowchart that depicts the entire NSF proposal and award process (and associated timeline) is included in the GPG as [Exhibit III-1](#).

A comprehensive description of the Foundation's merit review process is available on the NSF website at: http://nsf.gov/bfa/dias/policy/merit_review/.

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

One of the strategic objectives in support of NSF's mission is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions must recruit, train, and prepare a diverse STEM workforce to advance the frontiers of science and participate in the U.S. technology-based economy. NSF's contribution to the national innovation ecosystem is to provide cutting-edge research under the guidance of the Nation's most creative scientists and engineers. NSF also supports development of a strong science, technology, engineering, and mathematics (STEM) workforce by investing in building the knowledge that informs improvements in STEM teaching and learning.

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

A. Merit Review Principles and Criteria

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

1. Merit Review Principles

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

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

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

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

2. Merit Review Criteria

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

The two merit review criteria are listed below. **Both** criteria are to be given **full consideration** during the review and decision-making processes; each criterion is necessary but neither, by itself, is sufficient. Therefore, proposers must fully address both criteria. ([GPG Chapter II.C.2.d.i.](#) contains additional information for use by proposers in development of the Project Description section of the proposal.) Reviewers are strongly encouraged to review the criteria, including [GPG Chapter II.C.2.d.i.](#), prior to the review of a proposal.

When evaluating NSF proposals, reviewers will be asked to consider what the proposers want to do, why they want to do it, how they plan to do it, how they will know if they succeed, and what benefits could accrue if the project is successful. These issues apply both to the technical aspects of the proposal and the way in which the project may make broader contributions. To that end, reviewers will be asked to evaluate all proposals against two criteria:

- **Intellectual Merit:** The Intellectual Merit criterion encompasses the potential to advance knowledge; and
- **Broader Impacts:** The Broader Impacts criterion encompasses the potential to benefit society and contribute to the achievement of specific, desired societal outcomes.

The following elements should be considered in the review for both criteria:

1. What is the potential for the proposed activity to
 - a. Advance knowledge and understanding within its own field or across different fields (Intellectual Merit); and
 - b. Benefit society or advance desired societal outcomes (Broader Impacts)?
2. To what extent do the proposed activities suggest and explore creative, original, or potentially transformative concepts?
3. Is the plan for carrying out the proposed activities well-reasoned, well-organized, and based on a sound rationale? Does the plan incorporate a mechanism to assess success?
4. How well qualified is the individual, team, or organization to conduct the proposed activities?
5. Are there adequate resources available to the PI (either at the home organization or through collaborations) to carry out the proposed activities?

Broader impacts may be accomplished through the research itself, through the activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. NSF values the advancement of scientific knowledge and activities that contribute to achievement of societally relevant outcomes. Such outcomes include, but are not limited to: full participation of women, persons with disabilities, and underrepresented minorities in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the United States; and enhanced infrastructure for research and education.

Proposers are reminded that reviewers will also be asked to review the Data Management Plan and the Postdoctoral Researcher Mentoring Plan, as appropriate.

Additional Solicitation Specific Review Criteria

All Breakthrough proposals will be evaluated on the basis of the one-page supplementary document articulating reasons why the research to be undertaken, if successful, would significantly change the field of cyber-physical systems.

All Breakthrough and Synergy project proposals with more than one investigator or institution, and all Frontier project proposals will be evaluated on the strength of their Collaboration Plans.

All Frontier project proposals will also be evaluated on the strength of their Education and Outreach Plans.

Proposals submitted with a Transition to Practice (TTP) option will be evaluated with careful attention to the following:

- The expected impact on the deployed environment described in the supplemental document;
- The extent to which the value of the proposed CPS research and development is described in the context of a needed capability and potential impact;
- The feasibility, utility, and interoperability of the capability in its proposed operational role;
- An option plan that addresses in its goals and milestones the demonstration and evaluation of a working system in the target environment;
- Tangible metrics described to evaluate the success of the capabilities developed, and the steps necessary to take the system from prototype status to production use; and

The appropriateness of the budget for the option plan. The supplemental document should explain how the additional budget will be used to execute the option 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, or Reverse Site Review.

Review and Selection Process:

Proposals submitted in response to this program solicitation will be reviewed by the process below.

A uniform review process will be conducted by NSF for all proposals received responding to this program solicitation. Multiple review panels of experts in the field and additional *ad hoc* reviewers as needed will be assembled. The number and topical clustering of panels will be determined according to the number and topical areas of the proposals received. Staff members from the other supporting agencies will be assigned to work cooperatively with NSF staff on each panel, as appropriate to the category of funding requested. Reviewers will be asked to evaluate proposals using two National Science Board approved merit review criteria and, if applicable, additional program specific criteria. Reviewers will be asked to formulate a recommendation to either support or decline each proposal. A summary rating and accompanying narrative will be completed and submitted by each reviewer. In all cases, reviews are treated as confidential documents. The Program Officer(s) assigned to manage a given proposal's review will consider the advice of reviewers and will formulate a recommendation. Upon conclusion of the review process, meritorious proposals may be recommended for funding by one of the participating agencies, the choice to be determined at the option of the agencies, not the proposer. Subsequent grant administration procedures will be in accordance with the individual policies of the awarding agency.

NSF Process: Those proposals selected for funding by NSF will be handled in accordance with standard NSF procedures. This process begins with NSF drafting and releasing the joint-agency solicitation, which includes program requirements.

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

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

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

DHS and DOT Process: Applications selected for funding by DHS and/or DOT will be awarded by NSF using funds transferred from DHS and/or DOT, respectively.

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

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

B. Award Conditions

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

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

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

Special Award Conditions:

Designated CPS project representatives (PI/co-PI/senior researchers and graduate students) must attend annual CPS PI meetings and participate in collaborative activities with the CPS-VO.

DHS and DOT Award Administration and Conditions:

Applications selected for funding by DHS and/or DOT will be awarded by NSF using funds transferred from DHS and/or DOT, and will thus follow NSF's award conditions described above.

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.

DHS and DOT:

Applications selected for funding by DHS and/or DOT will be awarded by NSF using funds transferred from DHS and/or DOT, respectively, and will thus follow NSF's award conditions described above.

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:

- David Corman, Program Director, CISE/CNS, 1175, telephone: (703) 292-8754, email: dcorman@nsf.gov
- Radhakisan Baheti, Program Director, ENG/ECCS, 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, 545, telephone: (703) 292-5348, email: bkramer@nsf.gov
- Bruce Hamilton, Program Director, ENG/CBET, 565, telephone: (703) 292-7066, email: bhamilto@nsf.gov
- Frank Olken, Program Director, CISE/IIS, 1125, telephone: (703) 292-4767, email: folken@nsf.gov
- Phillip Regalia, Program Director, CISE/CCF, 1115, telephone: (703) 292-8910, email: pregalia@nsf.gov
- Sylvia Spengler, Program Director, CISE/IIS, 1125, telephone: (703) 292-8930, email: sspengle@nsf.gov
- Kevin Thompson, Program Director, CISE/ACI, 1145, telephone: (703) 292-4220, email: kthomps@nsf.gov
- Ralph Wachter, Program Director, CISE/CNS, 1175, telephone: (703) 292-8950, email: rwachter@nsf.gov
- Daniel Massey, Program Director, DHS S&T, telephone: 202-254-0908, email: daniel.massey@hq.dhs.gov
- David Kuehn, Program Manager, DOT/FHWA, telephone: (202) 493-3414, email: david.kuehn@dot.gov
- Kevin Dopart, Program Director, DOT/ITS JPO, telephone: 202-366-8034, email: kevin.dopart@dot.gov

For questions related to the use of FastLane, contact:

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

For questions relating to Grants.gov contact:

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

IX. OTHER INFORMATION

The NSF website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this website by potential proposers is strongly encouraged. In addition, "NSF Update" is an information-delivery system designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF [Grants Conferences](#). Subscribers are informed through e-mail or the user's Web browser each time new publications are issued that match their identified interests. "NSF Update" also is available on NSF's website at https://public.govdelivery.com/accounts/USNSF/subscriber/new?topic_id=USNSF_179.

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>.

U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T) Homeland Security Advanced Research Projects Agency (HSARPA):

<http://www.dhs.gov/st-hsarpa>

U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA):

<http://www.fhwa.dot.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

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