Cyber-Physical Systems (CPS)

PROGRAM SOLICITATION
NSF 17-529

REPLACES DOCUMENT(S):
NSF 16-549

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

National Aeronautics and Space Administration

National Institutes of Health
- National Institute of Biomedical Imaging and Bioengineering
- National Cancer Institute

National Center for Advancing Translational Sciences

U.S. Dept. of Agriculture

National Institute of Food and Agriculture

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

February 20, 2017 - March 06, 2017

IMPORTANT INFORMATION AND REVISION NOTES

The Cyber-Physical Systems (CPS) program solicitation has been revised for the FY 2017 competition, and prospective Principal Investigators are encouraged to read the solicitation carefully. Among the changes are the following:

- The Breakthrough project category has been replaced by the CPS Small category; the intent of the category is similar, with a focus on new, emerging, and innovative ideas that will have high impact on the field of CPS;
- The Synergy project category has been replaced by the CPS Medium category; the intent of the category is similar with a focus on multi-disciplinary projects requiring integrated perspectives;
- The specific CPS research foci on Smart & Connected Communities (S&CC) and CPS Autonomy have been removed from the general solicitation; while these are still areas of interest to CPS, they are also addressed by new NSF solicitations: Smart & Connected Communities (S&CC; NSF 16-610; https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf16610) and Smart and Autonomous Systems (S&AS; NSF 16-608; https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf16608); and
- Language about the CPS research focus on System Design and Verification has been revised to emphasize rapid, real-time verification especially relevant in autonomous and semi-autonomous systems.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 17-1), which is effective for proposals submitted, or due, on or after January 30, 2017. Please be advised that proposers who opt to submit prior to January 30, 2017, must also follow the guidelines contained in NSF 17-1.

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) CPS Senior Steering Group.

Tremendous progress has been made in advancing CPS technology. 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, as the Internet of Things (IoT) scales to billions of connected devices — with the capacity to sense, control, and otherwise interact with the human and physical world — the requirements for dependability, security, safety, and privacy grow immensely. One barrier to progress is 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 that people can use or interact with and depend upon. Some of these may require high-confidence or provable behaviors. 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. We have also seen a convergence of CPS technologies and research thrusts that underpin Smart & Connected Communities (S&CC) and the Internet of Things (IoT). These domains offer new and exciting challenges for foundational research and provide opportunities for maturation at multiple time horizons.

In 2017, NSF is working closely with multiple agencies of the federal government, including the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T); the U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA), and through FHWA, the U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO); the National Aeronautics and Space Administration (NASA) Aeronautics Research Mission Directorate (ARMD); several National Institutes of Health (NIH) institutes and centers [including the National Institute of Biomedical Imaging and Bioengineering (NIBIB), Office of Behavioral and Social Sciences Research (OBSSR), National Cancer Institute (NCI), and National Center for Advancing Translational Sciences (NCATS)]; and the U.S. Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA, hereafter referred to as NIFA). Key goals are to identify basic CPS research directions that are common across multiple application domains, along with opportunities for accelerated transition to practice.

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

- **Small** projects may be requested for a total of up to $500,000 for a period of up to 3 years. They are well suited to emerging new and innovative ideas that will have high impact on the field of cyber-physical systems.
- **Medium** projects may be requested for a total budget ranging from $500,001 to $1,000,000 for a period of up to four years. They are well suited to multi-disciplinary projects that accomplish clear goals requiring integrated perspectives spanning the disciplines.
- **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, telephone: (703) 292-8754, email: dcorman@nsf.gov
- Radhakisan Baheti, Program Director, ENG/ECCS, telephone: (703) 292-8339, email: rbaheti@nsf.gov
- Sankar Basu, Program Director, CISE/CCF, telephone: (703) 292-7843, email: sabasu@nsf.gov
- Bruce Hamilton, Program Director, ENG/CBET, telephone: (703) 292-7066, email: bhamilto@nsf.gov
- Bruce Kramer, Program Director, ENG/CMMI, telephone: (703) 292-5348, email: bkramer@nsf.gov
- Anita Nikolich, Program Director, CISE/ACI, telephone: (703) 292-4551, email: anikolic@nsf.gov
- Wendy Nilsen, Program Director, CISE/IIS, telephone: (703) 292-2568, email: wnilsen@nsf.gov
- Sylvia Spengler, Program Director, CISE/IIS, telephone: (703) 292-8930, email: sspengle@nsf.gov
- Ralph Wachter, Program Director, CISE/CNS, telephone: (703) 292-8950, email: rwachter@nsf.gov
- Chengshan Xiao, Program Director, ENG/ECCS, telephone: (703) 292-4753, email: cxiao@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
- Yuri Gawdiak, Manager of Strategic Analysis, NASA ARMD, telephone: (202) 358-1853, email: yuri.o.gawdiak@nasa.gov
- Michael Read,NASA, telephone: (281) 2447656, email: michael.e.read@nasa.gov
- Vinay Pai, Program Director, NIH/NIBIB, telephone: (301) 451-4781, email: vinay.pai@nih.gov
- Danilo Tagle, Associate Director for Special Initiatives, NIH/NCATS, telephone: (301) 594-8064, email: danilo.tagle@nih.gov
- Bradford Hesse, Program Director, NIH/NCI, telephone: (301) 594-9904, email: bradford.hesse@nih.gov
- Daniel Schmoldt, National Program Leader, USDA-NIFA, telephone: (202) 720-4807, email: dschmoldt@nifa.usda.gov

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

- 10.310 --- USDA-NIFA Agriculture and Food Research Initiative
- 20.200 --- Highway Research and Development Program
- 43.001 --- National Aeronautics and Space Administration (Science)
- 47.041 --- Engineering
- 47.070 --- Computer and Information Science and Engineering
- 93.286 --- National Institute of Biomedical Imaging and Bioengineering
- 93.350 --- National Center for Advancing Translational Sciences
- 93.396 --- National Cancer Institute
- 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 Small projects, 20 Medium projects, and 2 Frontier projects are anticipated, subject to receipt of sufficient meritorious proposals and pending availability of funds.

Anticipated Funding Amount: $31,500,000

In FY 17, subject to receipt of sufficient meritorious proposals and pending availability of funds.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

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

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An individual can participate as PI, co-PI, or Senior Personnel, or Consultant 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-proposa 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, DOT, NASA, NIH, or NIFA 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: https://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: https://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:**

  For awards made by NSF, *Proposal & Award Policy & Procedures (PAPPG)* guidelines apply. [Proposals selected for funding by DHS and/or DOT will be awarded by NSF using funds transferred from DHS and/or DOT, respectively, and so they will follow NSF's *PAPPG*.]

  For awards made by NASA, contact the cognizant NASA Program Officer.

  For awards made by NIH, indirect costs on foreign subawards/subcontracts will be limited to eight (8) percent.

  For awards made by NIFA: Section 713 of the Consolidated Appropriations Act, 2016 (Pub. L. 114-113) limits indirect costs to 30 percent of the total Federal funds provided (or 42.857 percent of total direct costs) under each award. Therefore, when preparing budgets, you should limit your request for the recovery of indirect costs to the lesser of your institution's official negotiated indirect cost rate or the equivalent of 30 percent of total Federal funds awarded. See Part V section 7.9 of the NIFA Grants.gov Application Guide for further indirect cost information. See webpage at http://nifa.usda.gov/indirect-costs for options.

- **Other Budgetary Limitations:**

  Other budgetary limitations apply. Please see the full text of this solicitation for further information.

C. Due Dates

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

  February 20, 2017 - March 06, 2017

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. Indeed, it is also clear that CPS technologies are central to achieving the vision of Smart & Connected Communities (S&CC), including "Smart Cities," which spans these multiple sectors and includes the important attributes of efficiency, safety, and security.

Tremendous progress has been made in advancing CPS technology. We have explored foundational technologies that have spanned an ever-growing set of application domains, enabling breakthrough achievements in many disparate fields. At the same time, the demand for innovation continues to grow, and is driving the need to accelerate fundamental research to keep pace. The Internet of Things (IoT) represents one area of innovation that integrates many CPS technologies and that is poised for explosive growth that may well transform our lives. The IoT is creating an ecosystem with tens of billions of devices — and harnessing the power of the IoT requires us to identify foundational technologies that will foster an "Internet of Dependable and Controllable Things" and provide control algorithms that can transform IoT sensor data into action.

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, as the IoT scales to billions of connected devices — with the capacity to sense, control, and otherwise interact with the human and physical world — the requirements for dependability, security, safety, and privacy grow immensely. One barrier to progress is 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 that may include both design-time and real-time capabilities in highly dynamic environments.

The CPS program seeks to develop the core system science needed to design and build complex CPS that people can use and with which they can interact, including some that must exhibit high-confidence or provably safe behaviors. 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. In addition, we have strong interest in CPS foundational research that can have major impact over multiple time horizons including both potential for nearer-horizon transitions as well as longer-term, far-reaching significance.

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 2017, NSF is working closely with multiple agencies of the federal government, including the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T); the U.S. Department of Transportation (DOT) Federal Highway Administration (FHWA), and through FHWA, the U.S. DOT Intelligent Transportation Systems (ITS) Joint Program Office (JPO); the National Aeronautics and Space Administration (NASA) Aeronautics Research Mission Directorate (ARMD); several National Institutes of Health (NIH) institutes and centers [including the National Institute of Biomedical Imaging and Bioengineering (NIBIB), Office of Behavioral and Social Sciences Research (OBSSR), National Cancer Institute (NCI), and National Center for Advancing Translational Sciences (NCATS)]; and the U.S. Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA, hereafter referred to as NIFA). Key goals are to identify basic CPS research directions that are common across multiple application domains, along with opportunities for accelerated transition to practice.

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

- Pursue fundamental research in CPS that can be generalized to multiple domains;
- Identify early-stage CPS research that addresses important basic research needs for synergistic collaboration with mission agencies as described in II.C, and that 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:

- ***Internet of Things (IoT)*** — What are the foundational research elements needed to harness the power of the IoT? How do we go from the IoT to the "Internet of Dependable and Controllable Things" at enormous scale, and are new design approaches necessary? What new areas of CPS research emerge from this? How do we ensure the security, privacy, safety, and functionality of massive numbers of connected devices, including where there is human-system integration?

- ***CPS Security and Privacy*** — What foundational advances and new technologies are required to ensure that increasingly complex and distributed CPS are secure against malicious attacks and unintended faults? How can we ensure high confidence in system safety and functionality? What new methodologies can facilitate the appropriate use of sensitive information in the context of CPS while protecting personal privacy? Furthermore, how do we maintain privacy in the presence of existing side-channel information sources external to the target CPS (e.g., security cameras or other means that may be ancillary to the activity but provide identifying information)? Of particular interest is CPS security as it relates to applications in transportation (including personal and commercial automotive, aerospace, and maritime transport), manufacturing, and medical devices.

- ***System Design and Verification*** — 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 verify autonomous and mixed autonomous systems with humans in or on the loop? How do we mix real-time and design-time verification for these types of systems? How will approaches scale? 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? How do approaches change when we look for dependability or "do no harm" behaviors?

- ***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? How can we quantify or predict the potential impact? What are the architectural impacts?

- ***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? How do we quantify CPS impact on manufacturing processes and outcomes, including product quality? How can we secure all steps in the manufacturing process (including design, fabrication, and assembly), as well as secure manufacturing infrastructure?

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 and integration 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 open 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 may have requirements for certifiably safe or dependable systems behavior. 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.

The program welcomes projects that explore next and future 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. **It is essential that proposals not simply describe the development of a CPS, but also emphasize the areas of CPS research contributing to this development in which novel and foundational research contributions are being made**. 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, transportation, health, energy, and national security.

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 a 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 below. Experimentation on an actual cyber-physical system is required for

projects of greater than three years. Note: proposals that include testbed development should clearly specify why a new testbed is required for the proposed research, and should elaborate on how the testbed may support other researchers with similar needs.

II.B Classes of Proposals

The following three classes of research and education proposals that differ in scope and goals will be accepted:

Small Projects: Small projects may be requested with total budgets of up to $500,000 for periods of up to three years. They are well suited to emerging new and innovative ideas that will have high impact on the field of cyber-physical systems. The proposed research should clearly identify and explain a major advance in fundamental CPS science and/or CPS technology. Proposals for Small 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 impact the field of cyber-physical systems. This statement must be submitted as a document under Supplementary Documents.

Medium Projects: Medium projects may be requested with total budgets ranging from $500,001 to $1,000,000 for periods of up to four years. They are well suited to multi-disciplinary efforts that accomplish clear goals requiring an integrated perspectives spanning the disciplines. Medium project descriptions must be comprehensive and well-integrated.

Frontier Projects: Frontier projects may be requested with total budgets ranging from $1,000,001 to $7,000,000 for periods of four to five years. 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).

All projects of more than three years in duration must include experimentation on an actual cyber-physical system.

II.B.1 Other Funding Opportunities: The CPS program notes the Computing Research Infrastructure (CRI; see NSF 15-590) and Major Research Instrumentation (MRI; see NSF 15-504) 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 target 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. Please note that the mission agencies, in general, are looking to the CPS solicitation for basic research for new and creative project ideas that are **not** typically submitted to their agency solicitations. All proposals, whether targeted for a mission agency or NSF, will be reviewed by NSF panels adhering to standard review criteria for intellectual merit and broader impacts.

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

Within the DHS S&T, the Homeland Security Advanced Research Projects 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 federal Networking and Information Technology Research and Development (NITRD) CPS Senior Steering Group's 2012 CPS Vision Statement notes CPS research gaps and 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)

FHWA has interest in research and development that provides improved safety, mobility, and energy conservation in the development and operation of the highway system. At the same time, CPS for highway transportation must be scalable, reliable, adaptable, and secure while also being cost-effective.

In particular, FHWA is interested in fundamental research that also is aimed towards solving important public needs and can scale across transportation systems and modes, and into other domains. The approaches should consider the open nature of the transportation system, legacy components and processes, and the distributed nature of asset ownership and operations.

Consider the following examples of how CPS research could respond to public needs across transportation and other domains:

- A concierge service that provides first-mile and last-mile travel for people regardless of ability through various means such as automated, low-speed vehicles, shared services, or route information for traveler safety and convenience;
- Reducing energy and resources across the value chain of manufacturing to goods delivery through automation and optimization;
- Technologies that extend the infrastructure lifecycle and reduce costs through automated maintenance with little or no disruption of service; or
- Leveraging the differences between machines and people in sensing, analytics, and control to improve system safety, efficiency, and sustainability.

These only are illustrative examples of how CPS could result in public benefits for transportation. Investigators are encouraged to consider and propose truly novel solutions to a broad range of public needs that could overlap the examples above or be entirely different.

FHWA and other agencies within the U.S. DOT are focused on measuring impacts across programs including the impacts of innovative technologies on how cities operate. Accordingly, FHWA encourages CPS research that can quantify how these new technologies meet public needs and can measure the impact of new technology systems on public health, safety, mobility, economic performance, equity, or on the environment.

FHWA encourages leveraging existing testbeds, pilot deployments, and real-world data. More information about testbeds and pilot deployments is provided below under Connected Automated Vehicles.

Proposed solutions need to account for a combination of legacy equipment and new systems. Initial deployment of new technologies may begin in specific corridors, but 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. 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 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 automation, CV, and CV testbeds programs.

II.C.3 National Aeronautics and Space Administration (NASA) Aeronautics Research Mission Directorate (ARMD)

NASA Aeronautics Research Mission Directorate (ARMD) is interested in a cyber-physical systems approach to Assured Autonomy for Aviation Transformation. This is driven by mega trends including growth in global transportation demand, climate change, sustainability and energy use, and technology convergence. Ever-increasing levels of automation and autonomy are transforming aviation, and this trend will continue to accelerate. Safe integration of Unmanned Air Systems (UAS) into the National Air Space (NAS), for example, requires research in a several areas, including communications, human-machine interfaces, sense-and-avoid, and separation assurance. ARMD will help lead in the development of new technologies and research in integration of UAS in the NAS, systems verification and validation, real-time system wide safety, and human-machine interface harmonization among others.

NASA ARMD in particular is interested in research and development of trusted systems as a core component of all cyber-physical systems. A complete lifecycle environment will need to be established from requirements analysis, design, development, testing, verification & validation (V&V), implementation, and operational feedback and improvements. Research is required on what is the nature of "trust," key artifacts, design principles, development tools, and net centric operational systems that support, monitor, and improve in real-time system trust characteristics and capabilities. Ideally, trusted systems concepts, metrics, and tools will be multi-industry interoperable to account for systems-of-systems interactions between various heterogeneous: infrastructures, platforms, vehicles, and services in order to maximize research & development resources, student & discipline education & training, tool development and economies of scale for testing, V&V, and implementation.

Additionally, NASA ARMD's research and development of Trajectory Based Operations (TBO), Unmanned Aircraft Systems Traffic Management (UTM), Reduced Crew Operations (RCO), Network Enabled Air Traffic Management (ATM), and initial planning for robotic and automated airports will provide an ideal platform for Smart & Connected Communities efforts in an airport environment, i.e., "Smart Airports." NASA ARMD's advanced management system prototypes will heavily leverage the Federal Aviation Administration's (FAA) System-Wide Information Management System (SWIM) for real-time access to FAA and airline assets and decision-making systems. Extending these connections in a CPS framework to the landside airport assets, systems, and services (i.e., the Airport of Things) will enable the full systems-of-systems optimization in the NAS.

Research & Development proposals should reflect multi-industry/sector strategies and demonstrate integrated lifecycle connectivity ensuring appropriate forward and backward quality improvement loops.

NASA Johnson Space Center (JSC) is interested in developing a tele-operated or autonomous robotic dissection suite that fits within either the Microgravity Sciences Glovebox (MSG) or the Life Sciences Glovebox (LSG). This is a highly complex CPS that will need to operate in a very constrained environment with multiple research challenges. The system has the potential to save up to 40% of on-board crew time and also offers a possible groundbreaking demonstration of the possibilities for remote surgery or other assembly and repair tasks ideally suited for a dexterous robot.

Each robotic dissection suite will contain one flight unit, one ground robot control station, and a ground unit to support operator training. Once in place, these systems will allow ground operators, with the assistance of one crew member, to perform many of the rodent dissection tasks that currently need two crew members to perform. Using these advanced systems ground crews will lessen the burden of on-board crew members by controlling the robot for the dissection and tissue collection operations On-board crew, if needed, will be available to perform ancillary tasks such as setup/teardown, cleanup, sample transport out of MSG/LSG, injection, euthanasia, specimen placement, and tool change-out.

For robotic dissection suites to work, they must be able to operate in the ISS (International Space Station) environment and allow for safe interactions with the crew. They must meet all the ISS launch, interface, and safety requirements. The ground unit must be able to simulate the time delay and video quality experienced on the ISS, and the onboard suite must be able to operate given the time delay and video quality, as well as planned and unplanned loss of signal.

The suite also must be able to properly perform the dissection at the standard currently established by a trained ISS crew member. It must be able to recover and preserve primary and secondary rodent tissue successfully and in a timely manner, so as to prevent tissue degradation. Tools need to be appropriately sized and strong enough to cut through the tissue and bones of small rodents, and cleanable with disposable wipes.

We are looking for CPS research that enables tele-operation functionality as described above. The proposer should also include a Transition to Practice option that will result in an operational package to be used on the ISS in conducting experiments for rodent dissection.

II.C.4 National Institutes of Health (NIH)

The NIH expects to fund two general types of research projects:

a. **Small** 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 Small projects may be requested of approximately $100,000 per year in direct costs for a period of up to three years. Funding may include applicable indirect costs, with total budgets not to exceed $500,000.

b. **Medium** 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 Medium projects may be requested of between approximately $100,001 and $250,000 per year in direct costs for a period of three to four years. Funding may include applicable indirect costs, with total budgets ranging from $500,001 to $1,000,000.

Applications being proposed should be relevant to the missions of the participating NIH institutes:

NIBIB: The mission of the National Institute of Biomedical Imaging and Bioengineering (NIBIB) is to improve health by leading the development and accelerating the application of biomedical technologies. NIBIB is committed to integrating the physical and engineering sciences with the life sciences to advance basic research and medical care.

NCI: The National Cancer Institute (NCI) mission is to conduct and support research that will lead to a future in which we can prevent cancer before it starts, identify cancers that do develop at the earliest stage, eliminate cancers through innovative treatment interventions, and biologically control those cancers that we cannot eliminate so they become manageable, chronic diseases.

NCATS: The National Center for Advancing Translational Sciences (NCATS) strives to develop innovations to reduce, remove or bypass costly and time-consuming bottlenecks in the translational research pipeline in an effort to speed the delivery of new drugs, diagnostics and medical devices to patients. NCATS is particularly interested in a comprehensive matrix of human diseases and conditions with known targets and pathways, and all available drugs tested in humans, that can be used for discovery and development of targeted therapeutics — for facilitating the research and development of systems pharmacology aimed at the discovery of multi-target drugs and drug combinations.

The **NIH** encourages CPS research and technology development to enhance health, lengthen life, and reduce illness and disability. Specifically, the participating NIH institutes on this solicitation are interested in targeting this solicitation to support the development of CPS research and technology to achieve functional independence in humans; improve quality of life; assist with behavioral therapy and personalized care; monitor or generate efficacious readouts of therapeutic effects of therapies; and promote wellness/health.

Advances in sensors, wearable devices, and patient-facing technologies hold great promise in improving healthcare across the continuum from prevention to survivorship. Little is known, however, about how advances in CPS can integrate these technologies and interfaces to increase patient engagement and activation. In the healthcare setting, CPS systems such as wireless body area networks (WBANs), assistive healthcare systems, and wearable sensors and implantable devices are actively being developed to improve outcomes and quality of life, provide cost-effective healthcare, and potentially speed-up disease diagnosis and prevention. In nonclinical settings, consumer-oriented CPS research can create supportive home environments to accommodate residents' functional deficits while offering insights to patients and caregivers on how best to manage their own care outside of the healthcare setting.

One vision of medical CPS could be the development of personalized patient-care systems which are tightly knit with other non-medical CPS systems. Such a closed-loop environment could enable optimal and timely delivery of healthcare improvements at a significant cost reduction. It is envisioned that such systems will also generate a significant amount of data, and technologies for analyzing these data on-the-fly will need to be developed.

Examples of medical CPS research and technology development include, but are not limited to:

- Implementing CPS technology to reduce medical errors in intensive care units (ICUs);
- Developing prototypical closed-loop CPS for medical systems such as artificial organs or continuous monitoring systems;
- Implementing CPS technology for real-time monitoring and analysis of complex biomedical research systems such as microphysiological systems or cancer research models for understanding cancer biology;
- Pursuing approaches to enhance interoperability between various medical devices and/or systems;
- Developing human-system integration (HSI) applications designed to optimize the role of human cognition in relation to CPS support within the context of either clinical or consumer health environments;

Developing applications to monitor physiologic, motor, and cognitive functioning across environments to inform treatment and facilitate research;
- Developing approaches to understand the behavioral and social aspects of medical CPS implementations;
- Developing real-time patient-specific clinical decision-making approaches;
- Developing real-time data analytic techniques for medical CPS systems, such as machine learning approaches to develop on-the-fly analyses and prediction models;
- Developing CPS applications to improve access, utility, and management of biomedical big data for basic research; and
- Developing hospital-wide applications to decrease fragmentation, improve quality of care, and conserve costs by tracking medical assets and conjoining informatics data flows to enable a "learning healthcare system."

Applicants should describe how the ideas being proposed will address the healthcare needs of the end user (healthy individuals, patient populations with specific targeted diseases, persons with disability, and/or health disparity populations).

II.C.5 National Institute of Food and Agriculture (NIFA)

NIFA is pursuing an aggressive research agenda to meet the "grand challenges" for agriculture and society identified by the President's Council of Advisors on Science and Technology in its December 2012 report titled *Report to the President on Agricultural Preparedness and the Agriculture Research Enterprise*. These challenges have a common underlying theme: delivering food, fiber, fuel, and feed within a changing global climate while reducing agriculture's environmental footprint and managing biotic threats to production. NIFA has embarked on a multi-horizon research agenda that is addressing these challenges. Foundational and applied research in cyber-physical systems are an important element of this agenda.

These CPS efforts address USDA goals (http://www.usda.gov/documents/usda-strategic-plan-fy-2014-2018.pdf), including: protecting agricultural health to ensure access to safe, plentiful, and nutritious food (Goal 4.4); increasing agricultural opportunities by supporting a competitive agricultural system (Goal 1.1); contributing to clean and abundant water by protecting and enhancing water resources (Goal 2.3); and ensuring that U.S. agricultural resources contribute to global food security (Goal 3.1). The USDA/Research, Education, and Economics (REE) Action Plan (http://www.ree.usda.gov/ree/news/USDA_2014_REE_Action_Plan_08-2014_Final.pdf) is also supported through the following goals: sustainable intensification of agricultural production, sustainable use of natural resources, and education and science literacy. Furthermore, NIFA science goals are supported (http://nifa.usda.gov/about/pdfs/strat_plan_2014.pdf), including: advancing our Nation's ability to achieve global food security and fight hunger; optimizing the production of goods and services from working lands while protecting the Nation's natural resource base and environment; and ensuring the development of human capital, communities, and a diverse workforce. In the process, it is expected that projects will engage academia, industry, stakeholders/users, students, and other organizations to identify critical research needs and to conduct both basic and applied research, while providing training for the next generation of scientists, engineers, and technologists.

For this solicitation, NIFA encourages projects that advance science and technology applied to Smart & Connected Communities (both rural and urban) and to real-time agricultural data analytics and control. While other applications of CPS in agriculture might be considered, strong preference will be given to these two topics. Today's traditional CPS notions of control, sensing, and real-time behavior may require new perspectives on modeling, performance prediction, and control to account for the spatial, temporal, and environmental considerations fundamental to agriculture. We are interested in foundational technologies that can be developed and demonstrated in the context of agricultural challenges, and then rapidly converged into capabilities that will transition into practice.

Smart & Connected Communities (S&CC):

The "sharing economy" has explored and built new business models, new marketing opportunities, and new options for consumers. Much of that sharing has been facilitated by location-aware, take-anywhere technology, such as the smart phone. Now, by overlaying that expanded level of human connectivity with networks of connected devices and infrastructure, not just mobile phones, we create new possibilities to enhance the livability and sustainability of communities in both urban and rural settings. While the same basic needs for environmental, social, and economic sustainability exist for both urban and rural communities, solutions to meet those needs can vary quite dramatically.

The following two NIFA **goals** have been identified for S&CC in urban and rural settings, respectively:

1. Increased food and nutritional security through the development of high-output and efficient controlled-environment urban agriculture technologies and systems; and
2. More resilient, robust, and reliable agricultural systems leading to more viable and thriving rural communities.

Reduced population densities, fewer socio-economic resources, and a greater percentage of non-point source pollution means that metrics for rural sustainability will look much different than their urban counterparts. And yet, food security, clean air and water, mobility, quality jobs, disaster preparedness and mitigation, and good healthcare are desirable and important aspects of livability regardless of where one resides.

CPS **technology challenges** that are directly relevant to NIFA goals for S&CC include:

- Robust and intelligent control systems and sensors to help monitor, optimize, and manage an entire controlled-environment urban agriculture facility including physical environment (lighting, temperature, water, and fertilizers);
- Model-based development and control integrating horticultural knowledge of pests, cultivars tailored to controlled environments, and companion production;
- Integration of renewable energy sources such as solar technology and improved high-efficiency lighting based upon physics and photonics advances; and
- New connectivity paradigms and applications for integrated devices, communications, control systems, and databases in dispersed rural settings that enable overlain software to bring quality-of-life improvements to citizens for benefits such as education, health, economic development, mobility, or environmental quality.

Real-Time Agricultural Data Analytics and Control:

Addressing many of the agricultural grand challenges demands new advances in the integration of cyber-physical systems (including sensors, communication systems, and control systems) with real-time information and analytic engines tightly coupled with agriculture and food systems. This integration forms a large-scale cyber-physical system that enables data collected throughout the supply chain to

be analyzed and used for control and decision-making in other stages of production, processing, distribution, storage, and consumption. Much agricultural data is currently single-use and static. For example, current technology allows for the collection and use of many different types of agricultural data, from soil moisture and chemistry, meteorology and climate, crop and market conditions, and consumer nutrition and preference, to gene sequences and ecological variables. However, these data are often used only at the time and place of collection, and necessarily require a human in the loop. Datasets in many of these fields need to become dynamic (regularly updated, or real-time in some cases) and actively engage in control operations and decision-making in other segments of the supply chain. These datasets are massive and vary in scale and precision, which presents challenges for accessibility, analytics, interoperability, and persistence. Nonetheless, they have potential to significantly impact environmental quality, product traceability, agricultural input use, regional pest management, and system-wide sustainability.

NIFA is interested in new approaches for analytics that can extract actionable information from these datasets and provide real-time control of agricultural CPS. While application of these massive datasets and real-time analytics in controlling CPS may be difficult in many domains, the multiple time scales of agriculture offer an opportunity to reorient our thinking of real-time, and may be highly compatible with the processing and data delivery timelines for these massive datasets. Proposals should briefly present metrics and methodology for evaluating the metrics to show the impact of the research.

Given the integrative and multi- or trans-disciplinary nature of agricultural sciences, NIFA expects to fund primarily Medium projects. However, where fundamental CPS advances have a clear benefit to agriculture, Small projects would be considered for NIFA funding. In addition, Frontier projects that demonstrate an agriculture-related critical challenge would also be considered by NIFA, but funding will be limited to the lower end of the Frontier range.

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," "DOT," "NASA," "NIH," or "NIFA," 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 the joint sponsoring agencies.

II.D Transition to Practice (TTP) Option

Proposals for Small, Medium, 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 section, 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 Small projects, $400,000 for Medium 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. We also recognize that TTP option activities may need to overlap with the base project timeline to support the accelerated maturation and TTP goals. This may include early testing of theory, additional robustness in design, and higher fidelity simulation. Proposers should carefully describe in their TTP option description and budget justification the scope of this additional activity, especially if it is anticipated in the early project years.)

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, including potential partnering with government or industry entities that develop, control, operate, or maintain complex systems that will incorporate the TTP technology as well as provide access to knowledge about integration and/or interoperability with new and/or legacy systems;
- 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 "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: Frontier: Title**.

II.E CPS PI Meetings

The CPS program is aiming to expand and sustain a 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. Projects are encouraged to use the CPS-VO to coordinate activities and disseminate artifacts along with research results.

For all awards, one or more designated CPS project representative (PI/co-PI/senior personnel or **NSF-approved replacement**) must attend **every** annual CPS PI meeting held throughout the duration of a given CPS grant. Graduate students are also encouraged to attend. For collaborative projects, principal investigators (**or an NSF-approved replacement**) from **each** collaborating institution of a given project are expected to participate. Principal investigators or other project representatives are also **expected** to provide a poster and short video describing their project(s) that will be made available on the CPS-VO.

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.

For ENG REU supplements, PIs should contact their cognizant CPS Program Officer.

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 CPS solicitation.

III. AWARD INFORMATION

All awards made under this solicitation by NSF or NIH will be as grants or cooperative agreements as determined by the supporting agency. Note that NCATS will only make cooperative agreements. All awards under this solicitation by DHS, DOT, or NASA will be as grants or cooperative agreements or other contract vehicles as determined by the supporting agency.

All awards made under this solicitation by NIFA will be as standard grants. A standard grant is an award instrument by which the agency agrees to support a specified level of effort for a predetermined project period without the announced intention of providing additional support at a future date.

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 VI.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, or Consultant 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, DOT, NASA, NIH, or NIFA 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 14-579) or Grants Opportunities for Academic Liaison with Industry (GOALI; see PAPPG, Chapter II.E.4) 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.

For proposals that specifically target NIFA for sponsorship by designating NIFA as the requested funding agency in the Project Summary in accordance with the guidelines outlined in the Proposal Preparation Instructions, eligible applicants include: (1) State agricultural experiment stations; (2) colleges and universities (including junior colleges offering associate degrees or higher); (3) university research foundations; (4) other research institutions and organizations; (5) Federal agencies, (6) national laboratories; (7) private organizations or corporations; (8) individuals who are U.S. citizens, nationals, or permanent residents; and (9) any group consisting of 2 or more entities identified in (1) through (8). Eligible institutions do not include foreign and international organizations.

The eligibility criteria for all other proposals, including those targeting a specific agency other than NIFA for sponsorship, are as listed under "Who May Submit Proposals" above. Proposals that do not meet these criteria, and do not explicitly designate NIFA as the requested funding agency in the Project Summary, will be returned without review.

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: https://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: (https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

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

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

See Chapter II.C.2 of the GPG for guidance on the required sections of a full research proposal submitted to NSF. Please note that the proposal preparation instructions provided in this program solicitation may deviate from the GPG instructions.

The following information supplements the guidelines and requirements in the NSF PAPPG and NSF Grants.gov Application Guide:

Proposal Titles: Proposal titles must indicate the CPS program, followed by a colon, then the project class, followed by a colon, then the title of the project. For example, a CPS Frontier 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 Medium project would be **CPS: Medium: 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: Frontier: 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: Medium: 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. 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," "NASA" "DOT," "NIH," or "NIFA," 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 Small and Medium proposals, and up to 20 pages for Frontier proposals**.

Proposals that address a next-generation CPS application in conjunction with research in one or more of the three target areas should clearly 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;
- Clearly explain the research component(s) of the project and their specific contribution to CPS science and technology;
- Explain how research outcomes can be generalized to other areas of application;
- Explain how the project research fits the Program Description for the class of proposal (*Small*, *Medium*, 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;
- Provide a compelling rationale for the multi-institution structure of the project and an explanation of how effective collaboration will be assured, if the proposal involves a collaboration spanning multiple institutions; and
- Present a research plan including a **Gantt chart** with major tasks, milestones, and interdependencies.

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 separately submitted 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 Transition to Practice (TTP) 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) Justification for Small Proposals:

Proposals for Small 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 impact the field of cyber-physical systems. Specifically, the statement should justify why the research itself represents a foundational innovation in an emerging area -- not simply re-state the challenge problem. The emphasis should be on the broader scientific and societal impacts of the project. How will your research and application domain be transformed? How might advances extend to other CPS research and application domains? Strive to quantify the magnitude of potential impacts where possible. **Small proposals that do not include this justification, or justifications exceeding one page in length, will be returned without review.**

(3) Collaboration Plans for Small, Medium, and 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 Small, Medium projects 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 video-conferences, software repositories, etc.), and 4) specific references to the budget line items that support collaboration and coordination mechanisms. Note: the Collaboration Plan should **not** be used to expand discussions on your research activities***. It is not the location where research ideas or material that does not fit in the page limitations of the Project Description can be placed; rather, all research activities should reside within the Project Description section.*** Collaboration plans and proposed budgets should demonstrate that key personnel, and especially lead PIs, have allocated adequate time for both their individual technical contributions and the leadership of collaborative activities necessary to realize the synergistic effects of larger-scale research.

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 NSF.

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

(4) 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 under-representation 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.

(5) 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 Small projects, no larger than $400,000 for Medium 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.

(6) 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 Proposal & Award Policies & Procedures Guide (PAPPG), Chapter II.C.2j for further information about the implementation of this requirement. **Proposals that include Postdoctoral Mentoring Plans exceeding one page in length will not be accepted by FastLane.**

(7) 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 PAPPG,Chapter II.C.2j for full policy implementation.

For additional information see https://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 https://www.nsf.gov/cise/cise_dmp.jsp.

In the case of CPS, all projects are **strongly** encouraged to share results, including software 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 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 not be accepted by FastLane.

(8) Human Subjects Protection:

Proposals involving human subjects should include a supplementary document of no more than two pages in length summarizing potential risks to human subjects; plans for recruitment and informed consent; inclusion of women, minorities, and children; and planned procedures to protect against or minimize potential risks.

For research that involves human subjects but does not involve one of the six categories of research that are exempt under 45 CFR

Part 46, the supplementary document must address the following five issues: 1) risk to subjects, 2) adequacy of protection against risks, 3) potential benefits to the subjects and others, 4) importance of the knowledge to be gained, and 5) data and safety monitoring for clinical trials.

For research that involves human subjects and meets the criteria for one or more of the six categories of research that are exempt under 45 CFR Part 46, the supplementary document must address: 1) the justification for the exemption, 2) human subjects involvement and characteristics, and 3) sources of materials.

Inclusion of Women, Minorities, and Children must be addressed for all proposals that involve human subjects. When the proposed project involves clinical research, the supplementary document must address the proposed plans for inclusion of minorities and members of both genders (http://grants.nih.gov/grants/funding/women_min/women_min.htm), as well as the inclusion of children (http://grants.nih.gov/grants/funding/children/children.htm). Proposals including research involving human subjects must provide a Planned Enrollment Report (see http://grants.nih.gov/grants/funding/phs398/PlannedEnrollmentReport.docx). The Planned Enrollment Report, if included, does not count against the two-page limitation for this supplementary document.

For more information please go to this website: http://grants.nih.gov/grants/policy/hs/.

Further NSF guidelines on the use of human subjects is available in PAPPG, Chapter II.D.5.

(9) Vertebrate Animals:

Proposals involving vertebrate animals should include a supplementary document of no more than two pages in length. The committee will evaluate the involvement of live vertebrate animals as part of the scientific assessment according to the following five points: 1) proposed use of the animals, and species, strains, ages, sex, and numbers to be used; 2) justifications for the use of animals and for the appropriateness of the species and numbers proposed; 3) adequacy of veterinary care; 4) procedures for limiting discomfort, distress, pain and injury to that which is unavoidable in the conduct of scientifically sound research including the use of analgesic, anesthetic, and tranquilizing drugs and/or comfortable restraining devices; and 5) methods of euthanasia and reason for selection if not consistent with the *AVMA Guidelines on Euthanasia*.

Further NSF guidelines on the use of vertebrate animals can be found in PAPPG, Chapter II.D.4.

Single Copy Document: In the Single Copy Documents section, upload the following:

Collaborators and Other Affiliations Information:

For this solicitation, the *Collaborators & Other Affiliations* information specified in the *PAPPG* should be submitted using the spreadsheet template found at https://www.nsf.gov/cise/collab/. For each proposal, a completed spreadsheet for each PI, co-PI, or senior personnel must be uploaded directly into Fastlane in .xls or .xlsx format as a "Collaborator and Other Affiliations" Single Copy Document. NSF staff use this information in the merit review process to help manage reviewer selection; the spreadsheet will ensure the Collaborator and Other Affiliations information has a common, searchable format.

Note the distinction to (1) above for Supplementary Documents: the listing of all project participants is collected by the project lead and entered as a Supplementary Document, which is then automatically included with all proposals in a project. The Collaborators and Other Affiliations are entered for each participant within each proposal and, as Single Copy Documents, are available only to NSF staff. Collaborators and Other Affiliations due to participants listed on (1) that are not PIs, co-PIs, or senior personnel can be uploaded under Additional Single Copy Documents using Transfer File.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Indirect Cost (F&A) Limitations:

For awards made by NSF, *Proposal & Award Policy & Procedures (PAPPG)* guidelines apply. [Proposals selected for funding by DHS and/or DOT will be awarded by NSF using funds transferred from DHS and/or DOT, respectively, and so they will follow NSF's *PAPPG*.]

For awards made by NASA, contact the cognizant NASA Program Officer.

For awards made by NIH, indirect costs on foreign subawards/subcontracts will be limited to eight (8) percent.

For awards made by NIFA: Section 713 of the Consolidated Appropriations Act, 2016 (Pub. L. 114-113) limits indirect costs to 30 percent of the total Federal funds provided (or 42.857 percent of total direct costs) under each award. Therefore, when preparing budgets, you should limit your request for the recovery of indirect costs to the lesser of your institution's official negotiated indirect cost rate or the equivalent of 30 percent of total Federal funds awarded. See Part V section 7.9 of the NIFA Grants.gov Application Guide for further indirect cost information. See webpage at http://nifa.usda.gov/indirect-costs for options.

Other Budgetary Limitations:

Cost Sharing Requirements for awards made by NIFA:

In accordance with 7 USC 450i(b)(9), if a funded applied **Research or Integrated Project** with an applied research component, is commodity-specific and not of national scope, the grant recipient is required to match the USDA funds awarded on a dollar-for-dollar basis from non-Federal sources with cash and/or in-kind contributions.

For Equipment Grants: The amount of Federal funds provided may not exceed 50 percent of the cost of the equipment acquired using funds from the grant, or $50,000, whichever is less. Grantees are required to match 100 percent of Federal funds awarded from non-

Federal sources. The Secretary of Agriculture may waive all or part of the matching requirement if all three of the following criteria are met: (1) applicants must be a college, university, or research foundation maintained by a college or university that ranks in the lowest one third of such colleges, universities, and research foundations on the basis of Federal research funds received (see Table 2 following Part VIII for eligibility); (2) if the equipment to be acquired using funds from the grant costs not more than $25,000; and (3) has multiple uses within a single research project or is usable in more than one research project. If the institution believes it is eligible for the waiver for matching funds, the budget justification must include a letter signed by the institution's AR stating this information. NIFA will consider this justification when ascertaining final matching requirements or in determining if required matching can be waived. NIFA retains the right to make final determinations regarding matching requirements.

Budget Preparation Instructions:

Budgets for all projects must include funding for one or more designated CPS project representatives (PI/co-PI/senior researcher or NSF-approved replacement) 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. submitter's local time):

  February 20, 2017 - March 06, 2017

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: https://www.nsf.gov/bfa/dias/policy/merit_review/.

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

through the integration of research and education and broadening participation in NSF programs, projects, and activities.

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

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

A. Merit Review Principles and Criteria

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

1. Merit Review Principles

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

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

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

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

2. Merit Review Criteria

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

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

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

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

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

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

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

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

Additional Solicitation Specific Review Criteria

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

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

All Frontier 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.

Additional NIH Review Criteria:

The mission of the NIH is to support science in pursuit of knowledge about the biology and behavior of living systems and to apply that knowledge to extend healthy life and reduce the burdens of illness and disability. While many of the NIH and NSF review criteria are based on the same standards of scientific evaluation, some scoring mechanisms and programmatic emphases vary. For example, all proposals under consideration by NIH will be scored by their respective review panels using the NIH 1-9 scoring system, which does not include consideration of broader impacts. Additionally, proposers should pay particular attention to NIH clinical evaluation standards represented by criteria for human protections, inclusion of women, minorities, and children in the study population, and animal subjects' protections, as well as biohazards. In their evaluations of scientific merit, reviewers will be asked to consider the following criteria that are used by NIH:

Overall Impact. Reviewers will provide an overall impact/priority score to reflect their assessment of the likelihood for the project to exert a sustained, powerful influence on the research field(s) involved, in consideration of the following five core review criteria, and additional review criteria (as applicable for the project proposed). Reviewers will consider each of the review criteria below in the determination of scientific merit. An application does not need to be strong in all categories to be judged likely to have major scientific impact. For example, a project that by its nature is not innovative may be essential to advance a field.

Significance. Does the project address an important problem or a critical barrier to progress in the field? If the aims of the project are achieved, how will scientific knowledge, technical capability, and/or clinical practice be improved? How will successful completion of the aims change the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field?

Investigator(s). Are the PD(s)/PI(s), collaborators, and other researchers well suited to the project? If Early Stage Investigators or New Investigators, or in the early stages of independent careers, do they have appropriate experience and training? If established, have they demonstrated an ongoing record of accomplishments that have advanced their field(s)? If the project is collaborative or multi-PD/PI, do the investigators have complementary and integrated expertise; are their leadership approach, governance and organizational structure appropriate for the project?

Innovation. Does the application challenge and seek to shift current research or clinical practice paradigms by utilizing novel theoretical concepts, approaches or methodologies, instrumentation, or interventions? Are the concepts, approaches or methodologies, instrumentation, or interventions novel to one field of research or novel in a broad sense? Is a refinement, improvement, or new application of theoretical concepts, approaches or methodologies, instrumentation, or interventions proposed?

Approach. Are the overall strategy, methodology, and analyses well-reasoned and appropriate to accomplish the specific aims of the project? Are potential problems, alternative strategies, and benchmarks for success presented? If the project is in the early stages of development, will the strategy establish feasibility and will particularly risky aspects be managed?

If the project involves human subjects and/or NIH-defined clinical research, are the plans to address 1) the protection of human subjects from research risks, and 2) inclusion (or exclusion) of individuals on the basis of sex/gender, race, and ethnicity, as well as the inclusion or exclusion of children, justified in terms of the scientific goals and research strategy proposed?

Environment. Will the scientific environment in which the work will be done contribute to the probability of success? Are the institutional support, equipment and other physical resources available to the investigators adequate for the project proposed? Will the project benefit from unique features of the scientific environment, subject populations, or collaborative arrangements?

Where applicable, the following items will also be considered:

Protections for Human Subjects. For research that involves human subjects but does not involve one of the six categories of research that are exempt under 45 CFR Part 46, the committee will evaluate the justification for involvement of human subjects and the proposed protections from research risk relating to their participation according to the following five review criteria: 1) risk to subjects, 2) adequacy of protection against risks, 3) potential benefits to the subjects and others, 4) importance of the knowledge to be gained, and 5) data and safety monitoring for clinical trials.

For research that involves human subjects and meets the criteria for one or more of the six categories of research that are exempt under 45 CFR Part 46, the committee will evaluate: 1) the justification for the exemption, 2) human subjects involvement and characteristics, and 3) sources of materials. For additional information on review of the Human Subjects section, please refer to the Human Subjects Protection and Inclusion Guidelines.

Inclusion of Women, Minorities, and Children. When the proposed project involves human subjects and/or NIH-defined clinical research, the committee will evaluate the proposed plans for the inclusion (or exclusion) of individuals on the basis of sex/gender, race, and ethnicity, as well as the inclusion (or exclusion) of children to determine if it is justified in terms of the scientific goals and research strategy proposed. For additional information on review of the Inclusion section, please refer to the Guidelines for the Review of Inclusion in Clinical Research.

Vertebrate Animals. The committee will evaluate the involvement of live vertebrate animals as part of the scientific assessment according to the following five points: 1) proposed use of the animals, and species, strains, ages, sex, and numbers to be used; 2) justifications for the use of animals and for the appropriateness of the species and numbers proposed; 3) adequacy of veterinary care; 4) procedures for limiting discomfort, distress, pain and injury to that which is unavoidable in the conduct of scientifically sound research including the use of analgesic, anesthetic, and tranquilizing drugs and/or comfortable restraining devices; and 5) methods of euthanasia and reason for selection if not consistent with the AVMA Guidelines on Euthanasia. For additional information on review of the Vertebrate Animals section, please refer to the Worksheet for Review of the Vertebrate Animal Section.

Biohazards. Reviewers will assess whether materials or procedures proposed are potentially hazardous to research personnel and/or the environment, and if needed, determine whether adequate protection is proposed.

Budget and Period of Support. Reviewers will consider whether the budget and the requested period of support are fully justified and reasonable in relation to the proposed research.

For those proposals that are selected for funding consideration by participating NIH Institutes, the NIH will ask the applicant(s) to resubmit the proposal in an NIH-approved format directly to the Center for Scientific Review (CSR) at the NIH. Each of these NIH applications will be accompanied by a cover letter that associates the application with CPS. Applicants will not be allowed to increase the proposed budget or change the scientific content of the application in the resubmission to the NIH. These NIH applications, along with the summary statements generated based on the review, will be entered into the NIH IMPAC-II system.

Additional NIFA Review Criteria:

Adequacy of Facilities. Reviewers will assess the adequacy of the necessary research infrastructure capacity for the performing organization to conduct the proposed work.

Relevance. The extent to which the proposed research meets USDA-NIFA strategic goals and advances the sciences related to agriculture and food systems will be evaluated.

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.

NASA Process: Applications selected for funding by NASA will be transferred to NASA for their procurement process.

NIH Process: For those proposals that are selected for potential funding by participating NIH Institutes, the PI will be required to resubmit the proposal in an NIH-approved format directly to the Center for Scientific Review (http://www.csr.nih.gov/) of the NIH. PIs invited to resubmit to NIH will receive further information on resubmission procedures from NIH. An applicant will not be allowed to increase the proposed budget or change the scientific content of the proposal in the resubmission to the NIH as an NIH application. Indirect costs on any foreign subawards/subcontracts will be limited to eight (8) percent. These NIH applications will be entered into the NIH IMPAC II system. The results of the review will be presented to the involved Institutes' National Advisory Councils for the second level of review. Subsequent to the Council reviews, NIH Institutes will make their funding determinations and selected awards will be made. Subsequent grant administration procedures for NIH awardees, including those related to New and Early Stage Investigators (http://www.niaid.nih.gov/researchfunding/grant/Pages/aag.aspx), will be in accordance with the policies of NIH. Applications selected for NIH funding will use the NIH funding mechanisms.

Proposals that are funded by NIH are expected to be renewed as competing continuing applications. PIs should contact their NIH Program Officer for additional information. For information purposes, NIH PIs may wish to consult the NIAID web site, "All about Grants," which provides excellent generic information about all aspects of NIH grantsmanship, including competitive renewals (http://www.niaid.nih.gov/researchfunding/grant/Pages/aag.aspx).

NIFA Process: NIFA will make final funding decisions based on the results of the peer review process. Applications selected for funding by NIFA will be forwarded to the NIFA Awards Management Division for award processing in accordance with the NIFA procedures.

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 https://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 https://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag.

Special Award Conditions:

For all awards, one or more designated CPS project representatives (PI/co-PI/senior researcher or NSF-approved replacement) must attend annual CPS PI meetings and participate in collaborative activities with the CPS-VO throughout the duration of the grant.

Attribution of support in publications must acknowledge the joint program, as well as the funding organization and award number, by

including the phrase, "as part of the NSF/DHS/DOT/NASA/NIH/USDA-NIFA Cyber-Physical Systems Program."

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.

NASA Award Conditions:

Contact the cognizant NASA Program Officer for additional information.

NIH Award Conditions:

Contact the cognizant NIH organization Program Officer for additional information.

NIFA Award Administration and Conditions:

Within the limit of funds available for such purpose, the NIFA awarding official shall make grants to those responsible, eligible applicants whose applications are judged most meritorious under the procedures set forth in this solicitation. The date specified by the NIFA awarding official as the effective date of the grant shall be no later than September 30 of the federal fiscal year in which the project is approved for support and funds are appropriated for such purpose, unless otherwise permitted by law. The project need not be initiated on the grant effective date, but as soon thereafter as practical so that project goals may be attained within the funded project period. All funds granted by NIFA under this solicitation may be used only for the purpose for which they are granted in accordance with the approved application and budget, regulations, terms and conditions of the award, applicable federal cost principles, NIFA assistance regulations, and NIFA General Awards Administration Provisions at 7 CFR part 3430, subparts A through E and G.

The award document will provide pertinent instructions and information including, at a minimum:

1. Legal name and address of performing organization or institution to which the director has issued an award under the terms of this request for applications;
2. Title of project;
3. Name(s) and institution(s) of PDs chosen to direct and control approved activities;
4. Identifying award number and the Federal Agency Identification Number assigned by NIFA;
5. Project period, specifying the amount of time NIFA intends to support the project without requiring recompetition for funds;
6. Total amount of financial assistance approved for the award;
7. Legal authority(ies) under which the award is issued;
8. Appropriate Catalog of Federal Domestic Assistance (CFDA) number;
9. http://www.nifa.usda.gov/business/awards/awardterms.html to view NIFA award terms and conditions);
10. Approved budget plan for categorizing allocable project funds to accomplish the stated purpose of the award; and
11. Other information or provisions deemed necessary by NIFA to carry out its respective awarding activities or to accomplish the purpose of a particular award.

Changes in Project Plans:

a. The permissible changes by the grantee, PD(s), or other key project personnel in the approved project grant shall be limited to changes in methodology, techniques, or other similar aspects of the project to expedite achievement of the project's approved goals. If the grantee or the PD(s) is (are) uncertain as to whether a change complies with this provision, the question must be referred to the Authorized Departmental Officer (ADO) for a final determination. The ADO is the signatory of the award document, not the program contact.

b. Changes in approved goals or objectives shall be requested by the grantee and approved in writing by the ADO prior to effecting such changes. In no event shall requests for such changes be approved which are outside the scope of the original approved project.

c. Changes in approved project leadership or the replacement or reassignment of other key project personnel shall be requested by the grantee and approved in writing by the ADO prior to effecting such changes.

d. Transfers of actual performance of the substantive programmatic work in whole or in part and provisions for payment of funds, whether or not Federal funds are involved, shall be requested by the grantee and approved in writing by the ADO prior to effecting such transfers, unless prescribed otherwise in the terms and conditions of the grant.

e. Changes in Project Period: The project period may be extended by NIFA without additional financial support, for such additional period(s) as the ADO determines may be necessary to complete or fulfill the purposes of an approved project, but in no case shall the total project period exceed five years. Any extension of time shall be conditioned upon prior request by the grantee and approval in writing by the ADO, unless prescribed otherwise in the terms and conditions of a grant.

f. Changes in Approved Budget: Changes in an approved budget must be requested by the grantee and approved in writing by the ADO prior to instituting such changes if the revision will involve transfers or expenditures of amounts requiring prior approval as set forth in the applicable Federal cost principles, Departmental regulations, or grant award.

Responsible and Ethical Conduct of Research:

In accordance with sections 2, 3, and 8 of 2 CFR Part 422, institutions that conduct USDA-funded extramural research must foster an atmosphere conducive to research integrity, bear primary responsibility for prevention and detection of research misconduct, and maintain and effectively communicate and train their staff regarding policies and procedures. In the event that an application to NIFA results in an award, the Authorized Representative (AR) assures, through acceptance of the award, that the institution will comply with the above requirements. Award recipients shall, upon request, make available to NIFA the policies, procedures, and documentation to support the conduct of the training. See http://nifa.usda.gov/responsible-and-ethical-conduct-research for more information.

C. Reporting Requirements

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

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

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

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the NSF *Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at https://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.

NASA:

Contact the cognizant NASA Program Officer for additional information.

NIH:

Contact the cognizant NIH organization Program Officer for additional information.

NIFA:

Expected Program Outputs and Reporting Requirements:

The output and reporting requirements are included in the award terms and conditions (see http://www.nifa.usda.gov/business/awards/awardterms.html for information about NIFA award terms). If there are any program or award-specific award terms, those, if any, will be identified in the award.

Other NIFA Requirements:

Several federal statutes and regulations apply to grant applications considered for review and to project grants awarded under this program. These may include, but are not limited to, the ones listed on the NIFA webpage: http://nifa.usda.gov/federal-regulations.

If selected for funding, the applicants will be required to file the mandatory Felony Convictions or Tax Delinquent Status found in Part V., Section 4.12 of the NIFA Grants.gov Application Guide (Field 12 on the Form) for instructions regarding mandatory Felony Convictions or Tax Delinquent Status.

In addition, specific management information relating to an applicant shall be submitted on a one-time basis, with updates on an as-needed basis. This requirement is part of the responsibility determination prior to the award of a grant identified under this RFA, if such information has not been provided previously under this or another NIFA program. Copies of forms recommended for use in fulfilling these requirements will be provided to applicants as part of the pre-award process. Although an applicant may be eligible based on its status as one of these entities, there are factors that may exclude an applicant from receiving federal financial and non-financial assistance and benefits under this program (e.g., debarment or suspension of an individual involved or a determination that an applicant is not responsible based on submitted organizational management information).

The *NIFA Federal Assistance Policy Guide*, a compendium of basic NIFA policies and procedures that apply to all NIFA awards, unless there are statutory, regulatory, or award-specific requirements to the contrary, is available at http://nifa.usda.gov/policy-guide.

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, telephone: (703) 292-8754, email: dcorman@nsf.gov
- Radhakisan Baheti, Program Director, ENG/ECCS, telephone: (703) 292-8339, email: rbaheti@nsf.gov
- Sankar Basu, Program Director, CISE/CCF, telephone: (703) 292-7843, email: sabasu@nsf.gov
- Bruce Hamilton, Program Director, ENG/CBET, telephone: (703) 292-7066, email: bhamilto@nsf.gov
- Bruce Kramer, Program Director, ENG/CMMI, telephone: (703) 292-5348, email: bkramer@nsf.gov

- Anita Nikolich, Program Director, CISE/ACI, telephone: (703) 292-4551, email: anikolic@nsf.gov
- Wendy Nilsen, Program Director, CISE/IIS, telephone: (703) 292-2568, email: wnilsen@nsf.gov
- Sylvia Spengler, Program Director, CISE/IIS, telephone: (703) 292-8930, email: sspengle@nsf.gov
- Ralph Wachter, Program Director, CISE/CNS, telephone: (703) 292-8950, email: rwachter@nsf.gov
- Chengshan Xiao, Program Director, ENG/ECCS, telephone: (703) 292-4753, email: cxiao@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
- Yuri Gawdiak, Manager of Strategic Analysis, NASA ARMD, telephone: (202) 358-1853, email: yuri.o.gawdiak@nasa.gov
- Michael Read, NASA, telephone: (281) 2447656, email: michael.e.read@nasa.gov
- Vinay Pai, Program Director, NIH/NIBIB, telephone: (301) 451-4781, email: vinay.pai@nih.gov
- Danilo Tagle, Associate Director for Special Initiatives, NIH/NCATS, telephone: (301) 594-8064, email: danilo.tagle@nih.gov
- Bradford Hesse, Program Director, NIH/NCI, telephone: (301) 594-9904, email: bradford.hesse@nih.gov
- Daniel Schmoldt, National Program Leader, USDA-NIFA, telephone: (202) 720-4807, email: dschmoldt@nifa.usda.gov

For questions related to the use of FastLane, contact:

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

For questions relating to Grants.gov contact:

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

IX. OTHER INFORMATION

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

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

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/

National Aeronautics and Space Administration (NASA) Aeronautics Research Mission Directorate (ARMD):

http://www.aeronautics.nasa.gov/

National Institutes of Health (NIH):

National Institute of Biomedical Imaging and Bioengineering (NIBIB):

http://www.nibib.nih.gov

Office of Behavioral and Social Sciences Research (OBSSR):

http://obssr.od.nih.gov/

National Cancer Institute (NCI):

http://www.cancer.gov/

National Center for Advancing Translational Sciences (NCATS):

http://www.ncats.nih.gov/

U.S. Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA):

http://www.nifa.usda.gov/

http://nifa.usda.gov/policy-guide

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 https://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

X. APPENDIX

Legislative Authority:

The USDA-NIFA authority for this solicitation is contained in section 2(b) of the Competitive, Special, and Facilities Research Grant Act (7 U.S.C. 450i(b)), of the Agriculture and Food Research Initiative (AFRI). AFRI authorizes the Secretary of Agriculture to award competitive grants for fundamental and applied research, extension, and education to address food and agricultural sciences. AFRI awards are subject to the NIFA regulations found at 7 CFR Part 3430. NIFA's authority to participate in the issuance of a joint RFA is 7 U.S.C. § 3319b.