Smart and Autonomous Systems (S&AS)

PROGRAM SOLICITATION
NSF 16-608

National Science Foundation

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

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

December 19, 2016

December 11, 2017

Second Monday in December, Annually Thereafter

IMPORTANT INFORMATION AND REVISION NOTES

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.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Smart and Autonomous Systems (S&AS)

Synopsis of Program:

The **Smart and Autonomous Systems** (S&AS) program focuses on **Intelligent Physical Systems** (IPS) that are **cognizant**, **taskable, reflective**, **ethical, and knowledge-rich**. The S&AS program welcomes research on IPS that are aware of their capabilities and limitations, leading to long-term autonomy requiring minimal or no human operator intervention. Example IPS include, but are not limited to, robotic platforms and networked systems that combine computing, sensing, communication, and actuation. *Cognizant* IPS exhibit high-level awareness beyond primitive actions, in support of persistent and long-term autonomy. *Taskable* IPS can interpret high-level, possibly vague, instructions, translating them into concrete actions that are dependent on the particular context in which the IPS is operating. *Reflective* IPS can learn from their own experiences and those of other entities, such as other IPS or humans, and from instruction or observation; they may exhibit self-aware and self-optimizing capabilities. *Ethical* IPS should adhere to a system of societal and legal rules, taking those rules into account when making decisions. *Knowledge-rich* IPS employ a variety of representation and reasoning mechanisms, such as semantic, probabilistic and commonsense reasoning; are cognitively plausible; reason about uncertainty in decision making; and reason about the intentions of other entities in decision making.

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.

- Reid Simmons, Program Director, CISE/IIS, telephone: (703) 292-4767, email: resimmon@nsf.gov

- David Corman, Program Director, CISE/CNS, telephone: (703) 292-8754, email: dcorman@nsf.gov

- Samee Khan, Program Director, CISE/CNS, telephone: (703) 292-8061, email: skhan@nsf.gov

- Jack Snoeyink, Program Director, CISE/CCF, telephone: (703) 292-8910, email: jsnoeyin@nsf.gov

- Jie Yang, Program Director, CISE/IIS, telephone: (703) 292-4768, email: jyang@nsf.gov

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

- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 25 to 40

Subject to the availability of funds and quality of proposals received.

Approximately 15-25 awards will be Foundational proposals and 10-15 awards will be Integrative proposals.

Foundational projects are anticipated to range from $350,000 to $700,000 in total costs for up to three years. Integrative projects are anticipated to range from $500,000 to $1,400,000 in total costs for up to four years.

Anticipated Funding Amount: $16,500,000

Subject to the availability of funds.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

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

- Non-profit, non-academic organizations: Independent museums, observatories, research labs, professional societies and similar organizations in the U.S. associated with educational or research activities.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An investigator may participate as PI, co-PI, or Senior Personnel in no more than two proposals submitted in response to this solicitation.

In the event that an individual exceeds this limit, proposals will be accepted based on earliest date and time of proposal submission, i.e., the first two proposals received will be accepted and the **remainder will be returned without review. No exceptions will be made.**

The above limit applies only to proposals to the S&AS solicitation, not to the totality of proposals submitted to NSF.

Proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by NSF.

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* (PAPPG) guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.
  - 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:**

  Not Applicable

- **Other Budgetary Limitations:**

  Not Applicable

C. Due Dates

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

  December 19, 2016

  December 11, 2017

  Second Monday in December, Annually Thereafter

Proposal Review Information Criteria

Merit Review Criteria:

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

Award Administration Information

Award Conditions:

Standard NSF award conditions apply.

Reporting Requirements:

Standard NSF reporting requirements apply.

TABLE OF CONTENTS

I. INTRODUCTION

The goal of the **Smart and Autonomous Systems** (**S&AS**) program is to promote fundamental research into **Intelligent Physical Systems** (**IPS**), enabling us to realize physical systems that: (a) are aware of their capabilities and limitations; (b) understand high-level instructions given to them; (c) learn from experience to improve system performance; (d) take into account ethical norms when acting in the environment; and (e) are capable of reasoning over a diverse body of knowledge.

Consider five examples of IPS: (a) a fully autonomous vehicle that knows when the conditions of the environment (and the vehicle itself) are incompatible with self-driving; (b) a robot assistant that understands user intent from simple verbal instructions; (c) a network of sensors with reconfigurable sensory platforms, both hardware and software stack, that can adapt over time to the particularities of the deployed environment, improving its capabilities of sensing, data processing, storage, placement, and movement; (d) a smart grid that reasons about sensory load (numeric quantities), types of sensors (semantic knowledge), and anticipated events (commonsense reasoning); and (e) an unmanned aerial vehicle respecting privacy by deciding to turn off its camera when pointing inside a private residence.

A common characteristic of the above IPS examples is that they operate in the physical world for extended periods of time with minimal or no supervision by human operators. IPS will go beyond the capabilities of present-day physical systems and will be able to introspectively examine their own actions and assess the effects of those actions in the environments in which they operate, leading to greater autonomy and range of operations.

IPS are expected to be capable of ethical reasoning, such as incorporating societal values into their reasoning. The S&AS program encourages fundamental research on computational aspects of IPS that take into account autonomous adherence to an ethical system of societal and legal rules.

II. PROGRAM DESCRIPTION

The S&AS program promotes research into IPS that are **cognizant**, **taskable**, **reflective**, compliant with **ethical** norms, and **knowledge-rich**. This is especially relevant for: (a) operating in environments that are dynamic, uncertain, partially observable, and only approximately modeled; and (b) executing tasks that cannot be completely specified *a priori,* meaning that IPS will need to adapt to unanticipated contingencies, possibly while deployed for extensive periods of time. Examples for (a) could be IPS operating in homes, on roadways, or in factory settings. Examples for (b) could be IPS operating in space stations, Arctic expeditions, or exploratory deep-sea missions.

The objective of the S&AS program is to enable research on a new generation of IPS enabling us to realize physical systems that are *cognizant,* exhibiting high-level cognition beyond primitive actions, in support of persistent and long-term autonomy with a sound plan built on solid algorithmic or mathematical foundations. *Taskable* IPS should enable users to specify desired behaviors and outcomes in a natural and concise, yet possibly vague manner, with a quantifiable confidence that the system will perform correctly within that intent. *Reflective* IPS should be capable of adjusting their behaviors, or learning new behaviors based on their own experiences, observations, and explicit or implicit interactions with other entities, such as other IPS or humans. *Ethical* IPS should adhere to a system of societal and legal rules, operating in a way that does not violate accepted ethical norms. This program aims to push the research frontiers closer to this vision of smart and autonomous systems. To achieve this vision, systems need to be *knowledge-rich,* including capabilities for semantic, probabilistic and commonsense reasoning and meta-reasoning. They need to be capable of reasoning about uncertain, dynamic environments, and should be able to acquire and understand knowledge from other entities for improving their models of the world and for improving their behaviors, responses, and interactions.

Research Themes

The S&AS program welcomes research advancing the science of IPS. The focus of this program is specifically on intelligent *physical* systems. All proposals must address their research in this context.

Note that **research relevant only to purely software (non-embodied) agents is out of scope of the S&AS program**. All proposals submitted to S&AS must demonstrate relevance to the design and performance of a specified intelligent physical system.

The following list is intended to be illustrative, but non-exhaustive, of the types of research that the S&AS program anticipates supporting. Proposals need not address all of these example themes, but should be of sufficient scope that they make meaningful progress towards the objectives of the program.

- **Cognizant**: IPS should exhibit high-level awareness beyond primitive actions, in support of persistent and long-term autonomy. IPS should be aware of their own capabilities, understand their limitations, anticipate possible failures, undertake contingency planning, and recognize when they are operating incorrectly and adapt accordingly. This high-level awareness includes a variety of IPS capabilities, such as: (a) being capable of operating autonomously over extended periods of time, with minimal or no human supervision; and (b) acting in a manner that is understandable by their human collaborators, and being capable of explaining themselves and asking for help, when needed.

- **Taskable**: IPS should have the ability to accept high-level, possibly vague, instructions from humans and be capable of translating such goal-oriented directives into a suitable plan for sensing, reasoning, communicating, and acting through the underlying system architecture. Instruction modes for the IPS may include natural language, gestures, and end-user programming techniques, such as sketches and multi-modal dialog systems. IPS should be able to plan and execute a wide range of diverse tasks, in a wide variety of applications. IPS may take the initiative to achieve necessary or important tasks, should be interruptible, and should be capable of performing multiple tasks concurrently.

- **Reflective:** IPS should be capable of monitoring their actions, diagnosing problems, and optimizing, reconfiguring, and

repairing autonomously. IPS should learn and adapt to improve their behavior over time, including acquiring, modifying, and transforming their skills by augmenting their knowledge on how to perform tasks. These improvements can be the result of past experiences of the IPS when interacting with the environment; observations of how other entities, such as other IPS or humans, interact with the environment; or instructions received by the IPS on how to perform tasks. IPS are expected to operate over long periods of time with little or no human intervention (i.e., there is no expectation of a human operator modifying the IPS behavior by making changes to its design or configuration). As a result, IPS are expected to continually adjust their behaviors and be capable of adapting to the particular contexts in which they are operating, even when specifics of those contexts were not initially modeled.

- **Ethical**. IPS should adhere to an ethical system of societal and legal rules. IPS are expected to be capable of ethical reasoning, such as incorporating societal values into their reasoning. When reasoning about how their actions might affect the environment, IPS should consider not only how to achieve their tasks but also the consequences of their actions, from an ethical perspective. IPS should recognize moral imperatives, and avoid commands and actions that violate those dictates. Ethical IPS should recognize when multiple moral imperatives are in conflict and correctly apply ethical decision making.

- **Knowledge-Rich**. IPS should be able to represent and reason with knowledge at multiple levels of abstraction. IPS should be capable of quantitative and qualitative reasoning, leading to facility with high-level semantic concepts. IPS may reason using multiple models, such as symbolic, ontological, probabilistic, mixed, and commonsense reasoning models. IPS should be capable of meta-reasoning, introspectively reasoning about their own reasoning capabilities and limitations.

Relationship to other NSF Programs

The S&AS program has intellectual connections to other NSF programs, particularly the National Robotics Initiative (NRI) and Cyber-Physical Systems (CPS) programs. This section provides a discussion of the distinctions between these programs. While the three programs overlap in terms of some application areas, they differ in the research themes upon which they focus and in their ultimate program goals, as well as the tools and approaches used.

The NRI program (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503641&org=CISE&from=home) focuses on **co-robots** -- robots that collaborate with people. As co-robots mature, new questions arise in how co-robots will scale to achieve **collaborations** of multiple robots with multiple humans; how co-robots can be designed to achieve a **variety** of tasks in a variety of environments, with minimal modification to the hardware and software; how co-robots can **utilize large data sets** to learn to perform more effectively and efficiently; and how the design of the co-robots' hardware and software can facilitate **large-scale, reliable operation**.

The CPS program (https://www.nsf.gov/funding/pgm_summ.jsp?pims_id=503286&org=CISE&from=home) focuses on engineered systems that seamlessly integrate computational algorithms and physical components. There is specific focus on the **design**, **verification**, **real-time control**, and **adaptability** of communicating, distributed, embedded systems. The program seeks principles that unify computation and physics, and that facilitate the design, implementation, and verification of hybrid systems. The program is interested in system components (hardware and software) that are modular and interoperable, and in architectures that facilitate the design and operation of such systems. The program supports research in the safety, security, reliability, and trustworthiness of such systems.

The S&AS program focuses on IPS that are aware of their own capabilities and limitations, require minimal or no human intervention, are able to learn and adapt their behaviors, and are deployed for the purpose of long-term interaction with entities based on knowledge-rich information. The research themes for S&AS include IPS being: (a) **cognizant** of their capabilities and limitations; (b) **taskable** to execute high-level and possibly vague instructions; (c) **reflective** to improve performance over time; and (d) **ethical,** adhering to societal and legal rules. All of these themes are couched in the context of (e) **knowledge-rich** systems that perform various types of reasoning, including semantic, probabilistic, and commonsense reasoning.

We strongly encourage the proposers to read these related solicitations to determine which program best fits their proposal. Proposers are reminded that, consistent with the requirements of the NSF PAPPG, proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by NSF or other Federal agencies. **Duplicate or substantially similar proposals will be returned without review, including those substantially similar to previously declined proposals that have not been revised to address concerns raised by reviewers.**

Classes of Proposals

Proposals can be of either of the following two categories, which differ in scope and goals:

- **Foundational (FND)** projects focus on research into algorithms and technologies that directly support a specific characteristic or component of IPS. While foundational investigations are not required to utilize a physical testbed, they must engage in an evaluation designed to demonstrate relevance to an IPS specified in that project plan. Project budgets range from $350,000 to $700,000 in total costs for up to three years.
- **Integrative (INT)** projects focus on integrating two or more components of IPS into increasingly smart and autonomous systems. Integrative projects should have longer-term vision, with objectives that could not be attained simply by a collection of smaller projects provided with similar resources. Integrative projects **must** include evaluation of physical systems, preferably in real-world settings. Integrative projects are encouraged to have multiple PIs, preferably from different disciplines. Project budgets range from $500,000 to $1,400,000 in total costs for up to four years.

Proposals in either category must respond to the goal of the S&AS program, as formulated in Section I of this solicitation.

PI Meetings

The S&AS program anticipates holding annual Principal Investigator (PI) meetings. Thus, proposal budgets should account for such trips to the Washington DC area for each of the project PIs and other team members as appropriate from all collaborating institutions. These meetings will be highlighted by technology demonstrations and progress reports, and will provide forums to discuss best practices, concerns, and high-risk, high-return ideas and challenges pertinent to the vision of smart and autonomous systems.

III. AWARD INFORMATION

Anticipated Type of Award: Continuing Grant or Standard Grant

Estimated Number of Awards: 25 to 40

Subject to the availability of funds and quality of proposals received.

Approximately 15-25 awards will be Foundational proposals and 10-15 awards will be Integrative proposals.

Foundational projects are anticipated to range from $350,000 to $700,000 in total costs for up to three years. Integrative projects are anticipated to range from $500,000 to $1,400,000 in total costs for up to four years.

Anticipated Funding Amount: $16,500,000

Subject to the availability of funds.

Estimated program budget, number of awards and average award size/duration are subject to the availability of funds.

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

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

- Non-profit, non-academic organizations: Independent museums, observatories, research labs, professional societies and similar organizations in the U.S. associated with educational or research activities.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An investigator may participate as PI, co-PI, or Senior Personnel in no more than two proposals submitted in response to this solicitation.

In the event that an individual exceeds this limit, proposals will be accepted based on earliest date and time of proposal submission, i.e., the first two proposals received will be accepted and the **remainder will be returned without review. No exceptions will be made.**

The above limit applies only to proposals to the S&AS solicitation, not to the totality of proposals submitted to NSF.

Proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by NSF.

Additional Eligibility Info:

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

International collaborations should be well-justified in terms of enhancing and adding value to the proposed research and education activities. Questions related to such collaborations should be directed to the NSF Office of International Science and Engineering (OISE) point of contact, Seta Bogosyan (sbogosya@nsf.gov).

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 Proposal & Award Policies & Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg. Paper copies of the PAPPG 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. PAPPG Chapter II.D.3 provides additional information on collaborative proposals.

See PAPPG Chapter II.C.2 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 PAPPG instructions.

Proposal Titles: Proposal titles must indicate the S&AS program, followed by a colon, then the project class ("FND" or "INT") followed by a colon, then the title of the project. For collaborative proposals (that is, ones submitted as separate submissions from multiple organizations), all participating institutions should use the same title, which should also include the keyword "COLLAB" followed by a colon. Thus, a single-institution Foundational proposal would have a title of the form **S&AS: FND: Title**, and a collaborative Integrative proposal would use the form **S&AS: INT: COLLAB: Title**.

Proposals from institutions that have RUI (Research in Undergraduate Institutions) eligibility should have a proposal title that begins with "S&AS: RUI:" followed by either "FND:" or "INT:", then "COLLAB:" (if applicable), followed by the title; for example, **S&AS: RUI: FND: COLLAB: Title**.

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

Project Description: Describe the research and education activities to be undertaken in **up to 15 pages**.

Proposers are reminded that, as specified in PAPPG:

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

For Integrative (INT) proposals, the Project Description **must** contain a separate section labeled "Evaluation." This section must include a discussion of how the project will be evaluated on a physical testbed, including a description of the testbed, proposed experiments, and evaluation metrics to be used. Proposals without this clearly-identifiable section may be returned without review.

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

Supplementary Documents:

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

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

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

   Mary Smith; XYZ University; PI

John Jones; University of PQR; Senior Personnel

Jane Brown; XYZ University; Postdoc

ABC Community College; Paid Consultant

Susan White; DEF Corporation; Unpaid Collaborator

Tim Green; ZZZ University; Subawardee

2. Collaboration Plans:

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 proposals that include more than one investigator **must include a Collaboration Plan** of up to 2 pages. The length of and degree of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Where appropriate, the Collaboration Plan should include: 1) the specific roles of the project participants in all organizations involved, nationally and internationally; 2) information on how the project will be managed across all the investigators, institutions, and/or disciplines; 3) identification of the specific coordination mechanisms that will enable cross-investigator, cross-institution, and/or cross-discipline scientific integration (e.g., yearly workshops, graduate student exchange, project meetings at conferences, use of the grid for videoconferences, software repositories, etc.), 4) specific references to the budget line items that support collaboration and coordination mechanisms, and 5) for Integrative proposals: a timeline for the integrative activities.

3. Data Management Plan (required):

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

See the NSF PAPPG for full policy implementation.

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

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

Single Copy Documents:

Collaborators and Other Affiliations Information: In lieu of the instructions specified in the PAPPG, Collaborators and Other Affiliations Information should be submitted as follows.

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.

Budget Preparation Instructions:

PI Meetings

The S&AS program anticipates holding annual Principal Investigator (PI) meetings. Thus, proposal budgets should account for such trips to the Washington DC area for each of the project PIs and other team members as appropriate from all collaborating institutions.

C. Due Dates

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

    December 19, 2016

    December 11, 2017

Second Monday in December, Annually Thereafter

D. FastLane/Grants.gov Requirements

For Proposals Submitted Via FastLane:

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

For Proposals Submitted Via Grants.gov:

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

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

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

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

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

1. All S&AS proposals must be responsive to the goal of the program. Specifically, proposals must explicitly address the goal of achieving Intelligent Physical Systems that exhibit long-term autonomy requiring minimal human intervention and are cognizant, taskable, reflective, ethical and knowledge-rich.

2. Integrative projects focus on research involving complete IPS, and are typically collaborative and multi-disciplinary. Thus, Integrative projects will also be reviewed on the basis of (1) the innovation in the integration of the system; and (2) the evaluation plan for the system in its intended (preferably real-world) setting, including testbed(s), proposed experiments, and evaluation metrics.

B. Review and Selection Process

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

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

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

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

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

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

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

B. Award Conditions

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

*These documents may be accessed electronically on NSF's Website at 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 *Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

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 Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

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:

- Reid Simmons, Program Director, CISE/IIS, telephone: (703) 292-4767, email: resimmon@nsf.gov

- David Corman, Program Director, CISE/CNS, telephone: (703) 292-8754, email: dcorman@nsf.gov

- Samee Khan, Program Director, CISE/CNS, telephone: (703) 292-8061, email: skhan@nsf.gov

- Jack Snoeyink, Program Director, CISE/CCF, telephone: (703) 292-8910, email: jsnoeyin@nsf.gov

- Jie Yang, Program Director, CISE/IIS, telephone: (703) 292-4768, email: jyang@nsf.gov

For questions related to the use of FastLane, contact:

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

For questions relating to Grants.gov contact:

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

For questions related to international collaborations, contact:

- Seta Bogosyan, Program Director, OD/OISE, telephone: (703)-292-4766, email: sbogosya@nsf.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.

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 (FASED) provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See the *NSF Proposal & Award Policies & Procedures Guide* Chapter II.E.6 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**   (703) 292-5111
  (NSF Information Center)**:**

- **TDD (for the hearing-impaired):**   (703) 292-5090

- **To Order Publications or Forms:**

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

     or telephone: (703) 292-7827

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

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

Policies and Important Links | Privacy | FOIA | Help | Contact NSF | Contact Web Master | SiteMap

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

Text Only