Resilient Interdependent Infrastructure Processes and Systems (RIPS)

PROGRAM SOLICITATION
NSF 14-524

National Science Foundation

Directorate for Computer & Information Science & Engineering
    Division of Computer and Network Systems

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

Directorate for Social, Behavioral & Economic Sciences

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

March 19, 2014

        Type I and Type II Proposals

IMPORTANT INFORMATION AND REVISION NOTES

INFORMATION WEBCAST: The EFRI Office will hold a information webcast on Tuesday January 21st at 1pm to discuss the RIPS program and answer questions about this solicitation. More details of the webcast will be posted on the EFRI website, www.nsf.gov/eng/efri, as they become available.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

    Resilient Interdependent Infrastructure Processes and Systems (RIPS)

Synopsis of Program:

Critical infrastructures are the mainstay of our nation's economy, security and health. These infrastructures are interdependent. For example, the electrical power system depends on the delivery of fuels to power generating stations through transportation services, the production of those fuels depends in turn on the use of electrical power, and those fuels are needed by the transportation services.

The goals of the **Resilient Interdependent Infrastructure Processes and Systems** (RIPS) solicitation are (1) to foster an interdisciplinary research community that discovers new knowledge for the design and operation of infrastructures as processes and services (2) to enhance the understanding and design of interdependent critical infrastructure systems (ICIs) and processes that provide essential goods and services despite disruptions and failures from any cause, natural, technological, or malicious, and (3) to create the knowledge for innovation in ICIs to advance society with new goods and services. The objectives of this solicitation are:

- Create theoretical frameworks and multidisciplinary computational models of interdependent infrastructure systems, processes and services, capable of analytical prediction of complex behaviors, in response to system and policy changes.
- Synthesize new approaches to increase resilience, interoperations, performance, and readiness in ICIs.
- Understand organizational, social, psychological, legal, political and economic obstacles to improving ICI's, and identifying strategies for overcoming those obstacles.

The RIPS solicitation seeks proposals with transformative ideas that will ensure ICIs services are effective, efficient, dependable, adaptable, resilient, safe, and secure. Successful proposals are expected to study multiple infrastructures focusing on them as interdependent systems that deliver services, enabling a new interdisciplinary paradigm in infrastructure research. Proposals that do not broadly integrate across the cyber-physical, engineering and social, behavioral and economic (SBE) sciences may be returned without review. Projects supported under this solicitation may undertake the collection of new data or use existing curated data depending on the category of award, and must recognize that a primary objective is integrative predictive modeling that can use the data to validate the models and which can be integrated into 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

- Konstantinos P. Triantis, ENG/CMMI, telephone: (703) 292-7088, email: ktrianti@nsf.gov

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- Angelos D. Keromytis, CISE/CNS, telephone: (703) 292-8061, email: adkeromy@nsf.gov

- Robert E. O'Connor, SBE/SES, telephone: (703) 292-7263, email: roconnor@nsf.gov

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- Ralph Wachter, CISE/CNS, telephone: (703) 292-8950, email: rwachter@nsf.gov

- Dennis E. Wenger, ENG/CMMI, telephone: (703) 292-8606, email: dwenger@nsf.gov

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

- 47.041 --- Engineering
- 47.070 --- Computer and Information Science and Engineering
- 47.075 --- Social Behavioral and Economic Sciences

Award Information

Anticipated Type of Award: Standard Grant

Estimated Number of Awards: 20

Two categories of awards are anticipated for this solicitation. The number of awards in each category will be dependent on the overall mix of proposals and the degree to which they meet the solicitation goals, Merit Review Criteria and Solicitation Specific Review Criteria. We anticipate up to 11 Type 1 awards and up to 9 Type 2 awards, dependent on the availability of funds.

Anticipated Funding Amount: $15,000,000

Types 1 Awards: Projects will have a duration of 1-2 years for a maximum of $300,000 for each project in total direct and indirect costs.

Type 2 Awards: Projects will be of 3 years in duration and in the range of $1 to $2.5 million maximum for each project in total direct and indirect costs.

Eligibility Information

Who May Submit Proposals:

> The categories of proposers eligible to submit proposals to the National Science Foundation are identified in the Grant Proposal Guide, Chapter I, Section E.

Who May Serve as PI:

> Because this program is meant to support interdisciplinary research, a minimum of three investigators is required per project, the Principal Investigator (PI) and two or more co-Investigators from the lead or participating institutions who are eligible to serve as PI or co-PI on NSF proposals submitted through their respective institutions. In order to ensure an interdisciplinary approach to studying ICIs principal investigators should represent three or more distinct disciplinary areas as described in this solicitation (computer science; engineering; social, economic, and behavioral sciences). Additional PIs or senior personnel may be added to cover other interdisciplinary needs of the project. The appropriateness of the research team's disciplinary composition and expertise will be factors in the merit review of the proposals (see Additional Review Criteria section).

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 may appear as a Principal Investigator (PI), co-PI, other senior personnel or investigator on one Type 1, and one Type 2 RIPS proposal for FY 2014. This limitation includes proposals submitted by a lead organization, any sub-award submitted as part of a proposal, or any collaborative proposal. All proposals and collaborative proposals that include a PI who does not meet these limits will be returned without review.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not Applicable

- **Preliminary Proposal Submission:** Not Applicable

- **Full Proposals:**
  - Full Proposals submitted via FastLane: NSF Proposal and Award Policies and Procedures Guide, Part I: Grant Proposal Guide (GPG) Guidelines apply. The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg.
  - Full Proposals submitted via Grants.gov: NSF Grants.gov Application Guide: A Guide for the Preparation and

Submission of NSF Applications via Grants.gov Guidelines apply (Note: The NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide)

B. Budgetary Information

- **Cost Sharing Requirements:** Inclusion of voluntary committed cost sharing is prohibited.

- **Indirect Cost (F&A) Limitations:** Not Applicable

- **Other Budgetary Limitations:** Other budgetary limitations apply. Please see the full text of this solicitation for further information.

C. Due Dates

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

  March 19, 2014

    Type I and Type II Proposals

Proposal Review Information Criteria

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

Award Administration Information

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

Reporting Requirements: Standard NSF reporting requirements apply.

TABLE OF CONTENTS

I. INTRODUCTION

The economic competitiveness and societal well-being of the United States are dependent upon the affordability, availability, quality and resilience of the services that its infrastructures provide. These infrastructures in turn are dependent on each other for their function. For example, the electrical power system depends on the delivery of fuels to power generating stations through transportation services, the production of those fuels depends in turn on the use of electrical power, and those fuels are needed by the transportation services. The disruption of electrical power impacts water, emergency services, finance, government services among others. All of these services are in turn dependent on communication and control services provided by the cyber-physical infrastructure, that has intranet and Internet services at its core, and which cannot function without power. This creates a complex set of interdependencies between infrastructure services that are challenging to conceptualize, understand, model and design across

multiple scales.

Infrastructures are pervasive, often highly decentralized and dynamic with interlocking parts - functionally and contractually. Infrastructures despite seeming permanent and durable are as strongly dependent on other infrastructures for operations in a manner that forms an ecology of systems, people, and technologies. This reimagines infrastructures as processes delivering services. Advances in materials, electronics, and computing are reshaping the ecology at scale. The rapid merging of cyberspace with traditional infrastructures has created new functionality and opportunities while simultaneously exporting the malignancies of cyberspace too. Similarly, as the importance and interdependency of these infrastructures grow, so does the societal pressure from nations, transnational corporations, and even individuals to control that growth.

Infrastructures and their interlocking connections are subject to disturbances from natural, technological and malicious sources generated at different timescales and with different intensities. How their services are impacted, both in terms of initial loss of quality and the trajectory of service restoration, and how people respond to this loss of service caused by these disturbances and/or day-to-day operations, is central to their long term viability. These features of infrastructure response to disturbances have broadly been labeled its resiliency, including the notion that the components may autonomously adapt and dynamically reconfigure during a disturbance to restore the lost functionality. Conceived as a process, infrastructure resiliency can be achieved by a myriad of strategies in addition to simple repair and replacement. Given the interdependent nature of infrastructures, their collective resiliency is a complex phenomenon that makes the design, management and control of ICI services in the economy extremely challenging but necessary.

In order to address this broad and integrative topic of ICIs design and behavior, we require the mapping of infrastructure components and processes to services, and a holistic, predictive understanding of interdependent critical infrastructures, including the human component of service production and consumption, and a new science of system design. In this context, an infrastructure is defined as a network of man-made systems and processes that function cooperatively and synergistically to produce and distribute a continuous flow of essential goods and services.

II. PROGRAM DESCRIPTION

The goal of the Resilient Interdependent Infrastructure Processes and Systems (RIPS) solicitation is to enhance the understanding and design of interdependent critical infrastructure systems and processes that provide essential goods and services despite disruptions and failures from any cause, natural, technological or malicious, and provide opportunity to innovate in ICIs to enrich society with new goods and services. There are currently eighteen critical infrastructures defined by the Department of Homeland Security and some of these are highly aggregated classifications, for example energy, of different essential infrastructures, such as power generation and distribution, and natural gas production and pipeline distribution.

Studies that advance the development of theoretical frameworks and predictive understanding are particularly encouraged. Successful proposals in all categories are expected to broadly integrate across the engineering, SBE and cyber-physical sciences, enabling a new interdisciplinary paradigm in infrastructure services research to develop theoretical frameworks for a predictive understanding.

From a computer science perspective the major transformation in the ICIs of the past few decades is the rapid adoption and pervasiveness of computing, communications and information communications technologies. This transformation has created new capabilities for awareness, autonomy, interoperability, cooperation, and control among the ICIs and is reshaping relationships among ICIs to engineering and society. ICIs composed of deeply interconnected cyber-physical-social systems promise significantly improved service resiliency at scale against all hazards - from nature, technology, organizational, regulatory, and cyberspace. Unfortunately, connections with cyberspace also open ICIs to new classes of threats and vulnerabilities. The challenge is to understand the computational foundations of resiliency for ICIs in the expanding design space of critical ICI services and technology in engineering, social, and computer sciences that greatly benefit society.

From an engineering perspective the understanding of the interdependencies in infrastructure systems continues to be a major challenge both in terms of defining appropriate theoretical constructs and in terms of defining and implementing appropriate interventions given current fiscal realities. The research has focused primarily on understanding of the physical interdependencies. Many times this understanding is informed by cyber-physical technologies. There have also been long standing efforts to integrate social and behavioral considerations (e.g. in the disaster literature). A systematic consideration of the three perspectives (engineering, cyber-physical, social/behavioral/economic) in an integrated fashion, however, will help provide a deeper understanding of what is meant by the interdependencies and the associated physical, information and social phenomena.

From a SBE science perspective the conceptualization of infrastructure systems as processes and services offers exciting opportunities for examining the relationships of social, economic, behavioral, psychological, geographic, policy and decision-science variables with engineering and cyber infrastructure elements. Social scientists and engineers have decades of experience in jointly examining the resilience of physical infrastructures to natural and technological hazards and extreme events. While such studies of resilience are welcome in this solicitation, this solicitation encourages research that integrates across SBE sciences, engineering and computer science disciplines and examines infrastructure systems and processes under normal conditions and over time. Individual, organizational, and community impacts upon the operation of infrastructure systems and processes, the roles of public policy and decision making in the provision of infrastructure services, and the spatial and economic factors that influence the performance of these processes are some of the many social science relevant investigations.

The interests include to:

- Understand the "systems ecology" of our interdependent infrastructures and services;
- Create conceptual frameworks or theories for understanding the processes and services of interdependent infrastructure systems from a multidisciplinary perspective;
- Test hypotheses and validating explanatory models through empirical work involving ICIs with either existing or newly collected data;
- Build multidisciplinary communities to address ICIs;
- Understand organizational, social, psychological, legal, political and economic obstacles to improving ICI's, and identifying resources and strategies for overcoming those obstacles;
- Understand human responses to the predicted performance of interdependent infrastructures;
- Improve control, integrity, and overall stability of services provided by ICIs;
- Explore the economics and governance of ICIs;
- Explore new multidisciplinary engineering approaches to increase; resilience, interoperability, performance, and readiness in ICIs;
- Expand the design space of alternatives, leveraging new interdependencies to increase resiliency to extreme conditions and future events;

- Determine the socio-economic value of new interdependencies of ICIs to meet societal demands;
- Create the knowledge that leads to innovative new ICI services and markets, facilitating transition to practice.

Some of the more frequently asked questions (FAQ's) that might arise for this solicitation are posed and answered in Section X. Appendix of this solicitation.

III. AWARD INFORMATION

Estimated Number of Awards: Two categories of awards are anticipated for this solicitation. The number of awards in each category will be dependent on the overall mix of proposals and the degree to which they meet the solicitation goals, Merit Review Criteria and Solicitation Specific Review Criteria. We anticipate up to 11 Type 1 awards and up to 9 Type 2 awards, dependent on the availability of funds.

Types 1 Awards: Theory, modeling, and metrics projects that will create the knowledge, methodologies and approaches to conceptualize and study interdependent infrastructures as processes and services. These awards are not intended for empirical testing of models or theories. These awards can also have the objective of team building that will help clarify the basic terminology, assumptions and premises that enable theories, model and metric formalizations for interdependent infrastructures as processes and services. Projects will have a duration of 1-2 years for a maximum of $300,000 for each project in total direct and indirect costs.

Type 2 Awards: These proposals support interdisciplinary research to conduct major new interdependent infrastructure research using empirical data. They are expected to include the creation of the knowledge, methodologies and approaches to conceptualize and study interdependent infrastructures as processes and services. Projects will be of 3 years in duration and in the range of $1 to $2.5million maximum for each project in total direct and indirect costs.

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

> The categories of proposers eligible to submit proposals to the National Science Foundation are identified in the Grant Proposal Guide, Chapter I, Section E.

Who May Serve as PI:

> Because this program is meant to support interdisciplinary research, a minimum of three investigators is required per project, the Principal Investigator (PI) and two or more co-Investigators from the lead or participating institutions who are eligible to serve as PI or co-PI on NSF proposals submitted through their respective institutions. In order to ensure an interdisciplinary approach to studying ICIs principal investigators should represent three or more distinct disciplinary areas as described in this solicitation (computer science; engineering; social, economic, and behavioral sciences). Additional PIs or senior personnel may be added to cover other interdisciplinary needs of the project. The appropriateness of the research team's disciplinary composition and expertise will be factors in the merit review of the proposals (see Additional Review Criteria section).

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 may appear as a Principal Investigator (PI), co-PI, other senior personnel or investigator on one Type 1, and one Type 2 RIPS proposal for FY 2014. This limitation includes proposals submitted by a lead organization, any sub-award submitted as part of a proposal, or any collaborative proposal. All proposals and collaborative proposals that include a PI who does not meet these limits 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: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg. Paper copies of the GPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.

- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov. The complete text of the NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions

link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

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

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via the NSF FastLane system. Chapter II, Section D.4 of the Grant Proposal Guide provides additional information on collaborative proposals.

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

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

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

Cover page:

The title of the proposed project should begin with the string "RIPS Type 1:" or "RIPS Type 2:" Make sure to identify this Solicitation Number on the Proposal Cover Sheet.

Supplementary Documents:

Management and Integration Plan: A Management and Integration Plan up to 3 pages in length is required for **Type 2 proposals**. The Management and Integration Plan should: a) list all Senior Personnel in the project (provide the last name, first name, and institution/organization); b) describe how the group effort will be coordinated; c) describe how the disciplinary components will be integrated; d) describe collaborations and partnerships and their integration with the project; e) describe how data, models, and ideas will be disseminated and shared with the research community and stakeholders. A clear time line of expected outcomes should be included, as well as plans for the integration of research and education.

Collaborators/Individuals with Conflicts of Interest (text-searchable PDF, in FastLane, under Additional Single Copy Documents). A list, in an alphabetized table, of the full names and institutional affiliations of all persons with potential conflicts of interest as specified in NSF's Grant Proposal Guide is required for **both Type I and Type II proposals**. For each PI, Co-PI, collaborator and other Senior Personnel, include all co-authors/editors and collaborators (within the past 48 months), all graduate advisors and advisees, and any other individuals or institutions with which the investigator has financial ties (please specify type). Include all PIs, Co-PIs, and other Senior Personnel from collaborative submissions to this solicitation.

B. Budgetary Information

Cost Sharing: Inclusion of voluntary committed cost sharing is prohibited

Other Budgetary Limitations:

Participants are required to attend grantees meetings in year 1 for Type 1 and 2 proposals, and in year 3 for Type 2 proposals. Therefore, the budget category Domestic Travel in appropriate budget years should include costs of travel for up to four members of the research team (including the PI and a least one other senior investigator) to the Washington, D.C. area. The goals of these grantee meetings are (a) to provide an opportunity for investigators to share research approaches and results, (b) promote interaction of Type 1 and Type 2 awardees, and (c) to encourage discussion of the new types of interdisciplinary collaborations necessary for RIPS research.

This program will support the costs of U.S.-based scientists and their students. International collaborators are encouraged to seek support from their respective funding organizations. Funding guidelines for involving international collaborators allow the following expenses to be included in the NSF budget: 1) Travel expenses for U.S. scientists and students participating in exchange visits integral to the project; 2) Limited project-related expenses for international partners to engage in research activities while in the United States as project participants; 3) Project-related expenses for U.S. participants to engage in research activities while abroad.

Budgets for Research Platforms and Facilities: For projects utilizing NSF research platforms (e.g., ships, research aircraft, etc.) or other shared use facilities (e.g., field instrumentation, analytical or experimental facilities) PIs must prepare their budgets consistent with the customary practices of the facility. Costs that are not borne by the facility must be included in the budget cap of $300K for Type 1 proposals and $2.5M for Type 2 proposals. Non-NSF facilities costs should be included in the proposal budget and count toward the applicable budget cap.

C. Due Dates

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

  March 19, 2014

    Type I and Type II Proposals

D. FastLane/Grants.gov Requirements

For Proposals Submitted Via FastLane:

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

For Proposals Submitted Via Grants.gov:

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

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

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

VI. NSF Proposal Processing and Review Procedures

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

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

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

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

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

A. Merit Review Principles and Criteria

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

1. Merit Review Principles

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

- All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge.
- NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the research itself, through activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. The project activities may be based on previously established and/or innovative methods and approaches, but in either case must be well justified.

- Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. If the size of the activity is limited, evaluation of that activity in isolation is not likely to be meaningful. Thus, assessing the effectiveness of these activities may best be done at a higher, more aggregated, level than the individual project.

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

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

2. Merit Review Criteria

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

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

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

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

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

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

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

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

Additional Solicitation Specific Review Criteria

- Projects are required to be interdisciplinary incorporating cyber-physical, engineering and SBE sciences; they should be focused on how the study of critical infrastructures advances the intellectual foundations of these disciplines, and advance the state of the art in the system science of critical infrastructure processes. This breadth of interdisciplinary research is expected to be reflected in the Principal Investigators involved in this project.

- These 3 questions reflect the major features of proposals responsive to the solicitation. (1) Does this address primarily address scientific research on interdependencies among critical infrastructures? (2) Does the research sufficiently reflect interests of the participating directorates? (3) Do the project personnel have the expertise to conduct necessary interdisciplinary research ?

- For Type II Proposals, **Supplementary Documentation** section, include a **Management and Integration Plan.** The Management and Integration Plan should: a) list all Senior Personnel in the project (provide the last name, first name, and institution/organization); b) describe how the group effort will be coordinated; c) describe how the disciplinary components will be integrated; d) describe collaborations and partnerships and their integration with the project; e) describe how data, models, and ideas will be disseminated and shared with the research community and stakeholders. A clear time line of expected outcomes should be included, as well as plans for the integration of research and education.

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 be completed and submitted by each reviewer. 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 http://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

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

Special Award Conditions:

At least one PI from a Type I and Type II grant will be expected to attend a PI meeting at the end of the first year of the project. At least one PI from each Type II grant will be expected to attend a PI meeting at the end of the third year of the project. Travel costs for these meetings should be included in the budget.

C. Reporting Requirements

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

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

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

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

VIII. AGENCY CONTACTS

Please note that the program contact information is current at the time of publishing. See program website for any updates to the points of contact.

General inquiries regarding this program should be made to:

- Konstantinos P. Triantis, ENG/CMMI, telephone: (703) 292-7088, email: ktrianti@nsf.gov

- Bruce K. Hamilton, ENG/CBET, telephone: (703) 292-7066, email: bhamilto@nsf.gov

- Daniel Hammel, SBE/BCS, telephone: (703) 292-4995, email: dhammel@nsf.gov

- Angelos D. Keromytis, CISE/CNS, telephone: (703) 292-8061, email: adkeromy@nsf.gov

- Robert E. O'Connor, SBE/SES, telephone: (703) 292-7263, email: roconnor@nsf.gov

- Zhi Tian, ENG/ECCS, telephone: (703) 292-2210, email: ztian@nsf.gov

- Ralph Wachter, CISE/CNS, telephone: (703) 292-8950, email: rwachter@nsf.gov

- Dennis E. Wenger, ENG/CMMI, telephone: (703) 292-8606, email: dwenger@nsf.gov

For questions related to the use of FastLane, contact:

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

For questions relating to Grants.gov contact:

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

IX. OTHER INFORMATION

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

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

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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.

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PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

X. APPENDIX

FAQ's

1. Question: What is meant by an infrastructure?

Answer: Infrastructures are defined as networks of systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services.

2. Question: Does an infrastructure system that I wish to study have to appear on the list of critical infrastructures as defined by the Department of Homeland Security?

Answer: No it does not have to appear on the list, but it must conform to the definition given of critical infrastructure: "the assets, systems, and networks, whether physical or virtual, so vital to the United States that their incapacitation or destruction would have a debilitating effect on security, national economic security, national public health or safety, or any combination thereof." You must be able to describe your infrastructure system according to the definition provided in the answer to Question 1 and this definition.

3. Question: Does an infrastructure system have to have the same extent or scale as those listed on the National Infrastructure Protection Plan (NIPP) list of critical infrastructures?

Answer: No, an infrastructure system might constitute a subsystem of the infrastructures as defined by in the NIPP. The NIPP, https://www.dhs.gov/national-infrastructure-protection-plan defines 18 critical infrastructures, http://www.dhs.gov/critical-infrastructure-sectors, several of which are the combination of multiple separate processes and services, such as:

- Energy, which includes the production and distribution of multiple energy carriers such as natural gas, coal, refined oil products, and electricity,
- transportation, which includes providing mobility to people and goods through combinations of air, rail, road, water-borne modes,
- telecommunications, which includes landline and mobile telephony, GPS signaling, internet and intranets, and associated data management and computing services;
- water, which includes the sourcing, storage, processing and distribution of water, and the recovery, processing, reuse and disposal of waste water.

It would be acceptable to study, for example, the interdependencies between certain subsystems of the energy infrastructure, the interdependencies of energy subsystems with telecommunications through an intranet, the delivery and customization of demand management strategies for different energy carriers through the internet, and water use for cooling and different energy carriers. You might also study the interdependencies of emergency services upon power, transportation, communication and water availability. The goal is to isolate an appropriate study scope to enable as rich a set of integrative questions to be addressed across disciplinary boundaries as possible, and to advance the study of infrastructures as services.

4. Question: Do the infrastructures we study have to be at the national scale?

Answer: You may study infrastructures at smaller scales than that of the nation or region as long as they constitute parts of the critical infrastructures defined above. For example, infrastructure interdependencies of communication, energy, and water can be seen at the scale of a building, neighborhood or city, as well as at a regional or national one. The questions and research outcomes should enable progress in understanding interdependency and resiliency across a broad range of scales, and very specific results on a particular location, that cannot be generalized, will be of limited value to this solicitation.

5. Question: What is meant by cyber-physical systems (CPS)?

Answer: A cyber-physical system is an interconnected network of cooperating sub-systems and devices with essential computational and physical characteristics that collectively can exercise purposeful control of a system. Cyber-physical systems include, for example, but are not limited to, medical monitoring systems, autonomous vehicular systems, and industrial process control systems.

6. Question: Will proposals that do not have a cyber-physical infrastructure component be considered?

Answer: No.

7. Question: Will proposals that do not have an engineering component be considered?

Answer: No.

8. Question: Will proposals that do not have a SBE component be considered?

Answer: No

9. What is meant by interdependent infrastructures?

Two infrastructures are interconnected if the processes by which one infrastructure delivers its services is affected by the state of the other. If both infrastructures require each other's services then they can be considered interdependent, if only one requires the other's services then it is dependent, examples of interdependent and dependent infrastructures are

- The interdependency of water and power: the requirement of water for cooling thermal cycle power plants and the need for power to deliver the water to the power plant,
- The interdependency of transportation and public health: the requirement of human resources to deliver public transportation and the dependence of health services on human resources arriving by public transportation,
- The interdependency of power and cyber-physical: the need of power for sensors and control systems and the dependence of power systems on detection and control of faults for safe and reliable operation,
- The short term dependency of financial services on communication and internet services, and the longer term dependency of communication services on the integrity of financial services.

We draw a distinction between interconnected and interdependent infrastructures. Two infrastructures can be interconnected at a given location, but not interdependent, because of geographical proximity such as the colocation of pipes and fiber optic cables, or electricity poles carrying telephone wires. The state of one infrastructure is affected by the state of the other through the spatial correlation but not by direct use of each other's service outputs.

10. Question: Can I study interconnected infrastructures?

Answer: No, proposals that just study infrastructures that are interconnected but not interdependent are not responsive to this solicitation.

11. Question: What is meant by resilient or resiliency, adaptability and robustness?

Answer: There have been many definitions of resiliency offered across different disciplines, and this solicitation does not wish to be overly prescriptive in defining these terms. A recent definition of resilience is "the ability to prepare and plan for, absorb, recover from, or more successfully adapt to actual or potential adverse events." The essential features of resiliency are the ability to absorb disturbances, or avoid disruptions, and "bounce back" and respond. The core element of resiliency is "bouncing back," which in this context is taken to mean the recovery of levels of service by the infrastructure after a disturbance. This service level recovery may be accompanied by changes in system components and structure that are temporary and permanent, which has been defined as adaptability. A linked concept is robustness, which is the loss of service that is induced by a disturbance. The boundary between when the system is responding robustly and when it is being resilient is not clear because the entire response is a dynamic trajectory governed by feedforward and feedback control interventions as well as design features. Proposals should be clear about the metrics and measures that they are employing for resiliency and robustness of given infrastructure services and how any data collected or used within their studies will be manipulated to compute such measures. Furthermore, resiliency is affected by how well we design interdependent systems to account for the wear and tear of day-to-day operations.

12. Question: I am specifically interested in the response of individual infrastructures to hazards. Is it appropriate to submit to this solicitation?

Answer: No, the goal of this solicitation is to focus on the interdependent nature of infrastructures. It is also preferred that the scope include not just responses to extreme events, such as natural disasters or large scale terrorist attacks, but to other more mild disturbances that may cause temporary disruption of service but not catastrophic loss.

13. Question: Is resiliency to deliberate attacks on interdependent infrastructures considered within the scope of the solicitation?

Answer: Yes, the source of the disturbance can be considered as a deliberate attempt to disrupt the smooth functioning of the infrastructure processes and delivered services. Again, a narrow focus on the disruption of a single infrastructure is not allowed.

14. Question: What defines "to broadly integrate across the disciplines of computer science, engineering, and SBE sciences"?

Answer: Integration can occur at many levels of research. This solicitation is particularly interested in discovering and elucidating

process-level interactions that occur among these disciplinary components within interdependent infrastructure services. Thus, not only must all components be fully integrated but all components must also be sufficient to convey their disciplinary processes and to convey the coupling of those disciplinary processes.

15. Question: If I plan to collect data that may contain personal information am I expected to consider legal and ethical issues around the collection and use of such data?

Answer: Yes, and you may wish to consult your IRB.

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