Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP)

PROGRAM SOLICITATION
NSF 16-519

REPLACES DOCUMENT(S):
NSF 15-531

National Science Foundation

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

Directorate for Social, Behavioral & Economic Sciences
- Division of Behavioral and Cognitive Sciences
- Division of Social and Economic Sciences

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

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

March 09, 2016

IMPORTANT INFORMATION AND REVISION NOTES

INFORMATION WEBCAST: The NSF will hold an informational webcast on **Friday, January 22, 2016 at 1:30pm** to discuss the CRISP program and answer questions about this solicitation. More details about the webcast will be posted on the CMMI website, http://www.nsf.gov/eng/cmmi, as they become available.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 16-1), which is effective for proposals submitted, or due, on or after January 25, 2016. Please be advised that proposers who opt to submit prior to January 25, 2016, must also follow the guidelines contained in NSF 16-1.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP)

Synopsis of Program:

Critical infrastructures are the mainstay of our nation's economy, security and health. These infrastructures are interdependent. They are linked to individual preferences and community needs. 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. Social networks, interactions, and policies can enable or hinder the successful creation of resilient complex adaptive systems.

The goals of the **Critical Resilient Interdependent Infrastructure Systems and Processes** (CRISP) solicitation are to: (1) foster an interdisciplinary research community of engineers, computer and computational scientists and social and behavioral scientists, that creates new approaches and engineering solutions for the design and operation of infrastructures as processes and services; (2) 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; (3) create the knowledge for innovation in ICIs so that they safely, securely, and effectively expand the range of goods and services they enable; and (4) improve the effectiveness and efficiency with which they deliver existing goods and services. These goals lead to the following specific objectives for this solicitation:

- To create new knowledge, approaches, and engineering solutions to increase resilience, performance, and readiness in ICIs.

- To create theoretical frameworks and multidisciplinary models of ICIs, processes and services, capable of analytical prediction of complex behaviors, in response to system and policy changes.
- To develop frameworks to understand interdependencies created by the interactions between the physical, the cyber (computing, information, computational, sensing and communication), and social, behavioral and economic elements of ICIs. These could include, but are not limited to, software frameworks for modeling and simulation using advanced cyber infrastructures, management, monitoring and real-time control of interdependent ICIs and novel software engineering methodologies.
- To study socioeconomic, political, legal and psychological obstacles to improving ICIs and identifying strategies for overcoming those obstacles.

The CRISP solicitation seeks to fund projects likely to produce new knowledge that can contribute to making ICI services more effective, efficient, dependable, adaptable, resilient, safe, and secure, taking into account the human systems in which they are embedded. 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. To meet the interdisciplinary criterion, proposals must broadly integrate across engineering, computer, information and computational science, and the social, behavioral and economic sciences. **Proposals that do not meet this criterion will 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 that can be integrated into decision making.

See Section X, Appendix for frequently asked questions (FAQs).

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.

- Elise Miller-Hooks, telephone: (703) 292-2162, email: elisemh@nsf.gov
- Bruce Hamilton, telephone: (703) 292-7066, email: bhamilto@nsf.gov
- Georgia Kosmopoulou, telephone: (703) 292-7466, email: gkosmopo@nsf.gov
- David J. Mendonca, telephone: (703) 292-7081, email: mendonca@nsf.gov
- Robert E. O'Connor, telephone: (703) 292-7263, email: roconnor@nsf.gov
- Rajiv Ramnath, telephone: (703) 292-4776, email: rramnath@nsf.gov
- Gurdip Singh, telephone: (703) 292-8061, email: gsingh@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 to 25

Two categories of awards are anticipated for this solicitation: Type 1 and Type 2. 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 approximately 15 Type 1 awards and up to approximately 10 Type 2 awards.

Anticipated Funding Amount: $26,500,000

Anticipated funding amount is pending availability of FY 2016 appropriation.

Type 1 Awards: Projects will be of 2 years in duration with a maximum total budget of $500,000.

Type 2 Awards: Projects will be of 3-4 years in duration with a total budget ranging from $1 million to $2.5 million.

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.

Who May Serve as PI:

Because this program is meant to support interdisciplinary research, a minimum of three investigators is required per project, including the Principal Investigator (PI) and two or more co-Investigators from the lead or participating institutions. Persons named as PI or co-PI must be eligible to serve as such on NSF proposals submitted through their respective institutions. In order to ensure an interdisciplinary approach to studying ICIs, proposals should

include and clearly identify at least one PI or co-PI who is an engineer, at least one who is a computer, information or computational scientist, and at least one who is a social, economic or behavioral scientist. Additional co-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 should be justified and will be a factor in the merit review of the proposal (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 only on one Type 1 and one Type 2 CRISP proposal. This limitation includes proposals submitted by a lead organization, any sub-award submitted as part of a proposal, or any collaborative proposal submitted as separate submissions from multiple organizations. An individual may not serve as a PI, coPI or senior investigator on more than one active award of the same type. **All proposals and collaborative proposals that include a PI, co-PI or other senior personnel or investigator who does not meet these limits will be returned without review.**

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

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

B. Budgetary Information

- **Cost Sharing Requirements:**

  Inclusion of voluntary committed cost sharing is prohibited.

- **Indirect Cost (F&A) Limitations:**

  Not Applicable

- **Other Budgetary Limitations:**

  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. submitter's local time):

  March 09, 2016

Proposal Review Information Criteria

Merit Review Criteria:

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

Award Administration Information

Award Conditions:

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

Reporting Requirements:

Standard NSF reporting requirements apply.

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I. INTRODUCTION

The economic competitiveness and societal well-being of the United States depend upon the affordability, availability, quality and resilience of the goods and services that its infrastructures provide. These infrastructures in turn are dependent on each other for their functions. An infrastructure is defined as a network of human-made systems and processes that function cooperatively and synergistically to produce and distribute a continuous flow of essential goods and services. 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, and government services, among others. All of these services are in turn dependent on computing, networking, data and control services provided by complex, multi-scale interdependent systems and software, which cannot function without power. All of these systems and processes are dependent on the human element. Together, this creates a complex set of interdependencies among infrastructure services that are challenging to conceptualize, understand, model and design across multiple scales.

Our view of infrastructures is evolving from collections of discrete physical and human components such as roads, bridges and buildings, or ambulances, hospitals and healthcare workers into an ecosystem of tightly interconnected and interdependent physical, cyber and human components. This places an emphasis on understanding and designing infrastructures as processes delivering services. Such understanding must address and include complex interdependencies among infrastructure systems. Advances in materials, electronics, and computing are reshaping infrastructures at different geographic scales from the local to the international, and have both positive and negative impacts. For example, the rapid merging of cyberspace with traditional infrastructures has created new functionality and opportunities while simultaneously exposing the vulnerabilities of cyberspace to these other infrastructures.

The creation and operation of these services under normal conditions is already challenging. In addition, infrastructures also are subject to disturbances from natural, technological and malicious sources at various timescales and intensities. Interdependencies among infrastructures add significant complexity to maintaining and restoring their functionality in these unfavorable situations. Predicting and managing human response to the loss of service in infrastructures exposed to hazards plays an important role throughout the cycle of responding to the disturbance, and is central to the long-term viability of infrastructures.

Resiliency encompasses the features of an infrastructure's inherent capacity to resist disturbances, initial loss of service quality, and trajectory of service restoration. Conceived as a process, infrastructure resiliency can be achieved by a myriad of strategies in addition to simple repair and replacement. Components may autonomously adapt and dynamically reconfigure during a disturbance to restore lost functionality, and people may change their behaviors to lower their demands on infrastructures and provide mutual support. Given the interdependent nature of infrastructures, their collective resiliency is a complex phenomenon that makes the design, management and control of independent critical infrastructure (ICI) services extremely challenging but necessary.

Addressing this broad and integrative topic of ICI design and behavior requires the mapping of infrastructure components from 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 *integrative* system design. This provides the context for the Critical Resilient Interdependent Infrastructure Systems and Processes (CRISP) solicitation described here.

II. PROGRAM DESCRIPTION

The goals of the CRISP solicitation are to enhance the understanding, design and operation 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 to provide opportunities to innovate in ICIs to enrich society with new goods and services. There are currently 18 critical infrastructures defined by the U.S. 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.

The diversity of types of infrastructures and the central role played by information and human behavior require a multi-disciplinary approach to studying, designing and controlling their performance under different operating conditions. Successful proposals in all categories are expected to broadly integrate across the engineering, social, behavioral and economic sciences, and computing, information, and computational science, enabling a new interdisciplinary paradigm in infrastructure services research to develop new representations and theoretical frameworks for predictive capability, system design and control.

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 fiscal realities. The research has focused primarily on understanding physical interdependencies and the design of redundant or hardened technology components to withstand disturbances. While important, the focus of this solicitation is not only the mitigation of failure, but also the engineering of the recovery processes to leverage the positive infrastructure interdependencies and minimize the negative ones.

From a computing perspective, the major transformation in the ICIs of the past few decades is the rapid adoption and pervasiveness of computing, communications and information technologies. ICIs comprised of deeply interconnected cyber-physical-social systems promise significantly improved service resiliency at different scales against all hazards from nature, terrorism, deliberate cyber-attack, or unintended software bugs. At the same time, connections with cyberspace have also made ICIs interdependent. A challenge is to understand the computational foundations of resiliency for ICIs and develop cyber-enabled real-time control and dynamic adaptation techniques to improve resiliency of ICIs. This includes cyber-physical systems research for real-time control and dynamic adaptation, new ways of creating, validating and verifying computational science tools (such as through the use of machine learning, product-line and model-driven engineering, and using advanced cyber infrastructures), sensing at scale and high-fidelity, multi-objective big data analytics.

From a social, behavioral, and economic sciences 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. 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 and behavioral science relevant investigations.

Engineers and social scientists 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 focuses on research that integrates across engineering, computer, information, computational and social/behavioral/economic science disciplines and examines infrastructure systems and processes under normal conditions and over time. A systematic consideration of the three perspectives (engineering, cyber, social/behavioral/economic) in an integrated fashion is expected to provide a deeper understanding of what is meant by the interdependencies and the associated physical, information and social phenomena. The concept of resilience should also undergo a broad re-examination to incorporate how the interdependency of infrastructures influences its antecedent definition and operational implementation. The initial loss of function might be influenced by the rapid spread of information across social networks and by more sophisticated control enabled by cyber-infrastructure. The interdependency of infrastructures may enhance the system response due to substitution of services from one infrastructure for another, such as telecommuting to avoid travel during bad weather, or reducing social contacts during disease outbreaks. On the other hand, the ability of failures in one infrastructure to cascade to another, and then rebound back to the original source, may exacerbate the fragility of the overall system. For instance, communication failure could cascade to power systems, and in turn could rebound to cause communication systems to fail. The recovery process might include substantial modifications to the way people use the damaged infrastructures, including substitutions of different services enabled by cyber-infrastructure. Various research activities in critical resilient infrastructure systems and processes that might be included in proposals are listed below (these activities are illustrative and should not be considered exhaustive or limiting).

- Design and test new scalable, multi-scale, modeling, simulation, real-time control and dynamic adaptation/configuration techniques (including software and software development techniques) to improve the resilience of ICIs;
- Improve control, integrity, and overall stability of services provided by ICIs;
- Understand the "systems ecology" of our interdependent infrastructures and services, including human, physical as well as cyber components;
- Create conceptual frameworks or theories for understanding the processes and services of interdependent infrastructure systems from a multidisciplinary perspective;
- Apply interdisciplinary knowledge to the design and management of interdependent critical infrastructure systems and processes required to meet societal needs;
- Test hypotheses and validate explanatory models through empirical work involving ICIs with either existing or newly collected data;
- Study risk assessment, incentives, network interactions and other mechanisms for facilitating the creation of resilient, efficient ICIs;
- Study socio-economic, political, legal, organizational, technical and psychological obstacles to improving ICIs and identify resources and strategies for overcoming those obstacles;
- Explore the economics and governance of ICIs;
- Explore impact of interactions and interdependencies between cyber and physical systems on correctness, safety and security properties 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; and
- Determine the socio-economic value of new interdependencies of ICIs to meet societal demands.

Also within the scope of the solicitation are studies that address more mild disturbances which may cause temporary disruption of service but not catastrophic loss. Such disturbances may originate within normal operations whose quality is compromised by, for example, slow degradation of infrastructure components or loss of social cohesion.

Two types of proposals will be submitted. See Section III, Award Information, for additional information.

See Section X, Appendix for frequently asked questions (FAQs).

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 approximately 15 Type 1 awards and up to approximately 10 Type 2 awards.

Type 1 Awards: Theory, modeling, data collection and metric formalizations projects that will create the knowledge, representations, methodologies, case studies and approaches to conceptualize and study interdependent infrastructures as processes, services and systems. These awards are not intended for empirical testing of models or theories. Projects will be of 2 years in duration for a maximum total budget of $500,000.

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 knowledge, representations, methodologies and approaches to conceptualize and study interdependent infrastructures as processes, services and systems. Projects will be of 3-4 years in duration with a total budget ranging from $1 million to $2.5 million.

Anticipated funding amount is pending availability of FY 2016 appropriation.

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.

Who May Serve as PI:

Because this program is meant to support interdisciplinary research, a minimum of three investigators is required per project, including the Principal Investigator (PI) and two or more co-Investigators from the lead or participating institutions. Persons named as PI or co-PI must be eligible to serve as such on NSF proposals submitted through their respective institutions. In order to ensure an interdisciplinary approach to studying ICIs, proposals should include and clearly identify at least one PI or co-PI who is an engineer, at least one who is a computer, information or computational scientist, and at least one who is a social, economic or behavioral scientist. Additional co-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 should be justified and will be a factor in the merit review of the proposal (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 only on one Type 1 and one Type 2 CRISP proposal. This limitation includes proposals submitted by a lead organization, any sub-award submitted as part of a proposal, or any collaborative proposal submitted as separate submissions from multiple organizations. An individual may not serve as a PI, coPI or senior investigator on more than one active award of the same type. **All proposals and collaborative proposals that include a PI, co-PI or other senior personnel or investigator who does not meet these limits will be returned without review.**

Additional Eligibility Info:

A nonacademic organization may participate through a subaward.

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.5 of the Grant Proposal Guide provides additional information on collaborative proposals.

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

The following instructions supplement the guidance in the GPG or NSF Grants.gov Application Guide.

Cover page:

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

Supplementary Documents:

Project Team Document: A Project Team document no longer than 1 page in length is required for **Type 1 proposals**. The Project Team document should list all Senior Personnel on the project and clearly indicate who is from each of the three distinct disciplinary areas (provide the last name, first name, institution/organization and discipline). An investigator identified as representing one of the three disciplinary areas (engineering; computer, information or computational science; and the social, behavioral and economic sciences), associated with the Directorates of Engineering (ENG), Computer & Information Science & Engineering (CISE) and Social, Behavioral and Economic Sciences (SBE), must have supporting information, **in the form of degrees, publications, patents and/or software products in that discipline**, for that designation in his/her Biographical Sketch.

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 on the project and clearly indicate who is from each of the three distinct disciplinary areas (provide the last name, first name, institution/organization and discipline) as in the Project Team Document for Type 1 proposals above; 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; and 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. An investigator identified as representing one of the three disciplinary areas (engineering; computer, information or computational science; and the social, behavioral and economic sciences), associated with the Directorates of ENG, CISE and SBE, must have supporting information, **in the form of degrees, publications, patents, and/or software products in the discipline**, for that designation in his/her Biographical Sketch.

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 at least one other senior investigator) to the Washington, D.C. area. The goals of these grantees meetings are to: (a) provide an opportunity for investigators to share research approaches and results, (b) promote interaction of Type 1 and Type 2 awardees, and (c) encourage discussion of the new types of interdisciplinary collaborations necessary for CRISP 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 U.S. as project participants; and 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 $500K 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. submitter's local time):

  March 09, 2016

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

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

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

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

A. Merit Review Principles and Criteria

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

1. Merit Review Principles

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

- All NSF projects should be of the highest quality and have the potential to advance, if not transform, the frontiers of knowledge.
- NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the research itself, through activities that are directly related to specific research projects, or through

activities that are supported by, but are complementary to, the project. The project activities may be based on previously established and/or innovative methods and approaches, but in either case must be well justified.
- Meaningful assessment and evaluation of NSF funded projects should be based on appropriate metrics, keeping in mind the likely correlation between the effect of broader impacts and the resources provided to implement projects. If the size of the activity is limited, evaluation of that activity in isolation is not likely to be meaningful. Thus, assessing the effectiveness of these activities may best be done at a higher, more aggregated, level than the individual project.

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

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

2. Merit Review Criteria

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

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

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

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

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

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

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

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

Additional Solicitation Specific Review Criteria

- Projects are required to be interdisciplinary incorporating engineering, computer, information and computational science, and social, behavioral and economic sciences; they should be focused on how the study of critical infrastructures advances the intellectual foundations of these disciplines, and the state of the art in the system science and engineering of critical infrastructure processes. This breadth of interdisciplinary research is expected to be reflected in the Principal Investigators involved in the project and the research plan. In order to ensure an interdisciplinary approach to studying ICIs, proposals should include and clearly identify at least one PI or co-PI who is a computer, information or computational scientist, at least one who is an engineer, and at least one who is a social, economic or behavioral scientist.
- Given the interdisciplinary nature of the proposals and the review process, proposals should be clear about their definitions of terms, particularly resiliency, which has acquired different meanings in different disciplines.
- The following 3 questions reflect the major features of proposals responsive to the solicitation. (1) Does the proposed project primarily address scientific research on interdependencies among critical infrastructures? (2) Does the proposed research sufficiently reflect interdisciplinary efforts and help cultivate an interdisciplinary research community in critical infrastructures? (3) Do the project personnel have the expertise to conduct necessary interdisciplinary research?

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 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 1 and Type 2 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 2 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 no later than 90 days prior to the end of the current budget period. (Some programs or awards require submission of more frequent project reports). No later than 120 days following expiration of a grant, the PI also is required to submit a final project report, and a project outcomes report for the general public.

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

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

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

- Elise Miller-Hooks, telephone: (703) 292-2162, email: elisemh@nsf.gov
- Bruce Hamilton, telephone: (703) 292-7066, email: bhamilto@nsf.gov
- Georgia Kosmopoulou, telephone: (703) 292-7466, email: gkosmopo@nsf.gov
- David J. Mendonca, telephone: (703) 292-7081, email: mendonca@nsf.gov
- Robert E. O'Connor, telephone: (703) 292-7263, email: roconnor@nsf.gov
- Rajiv Ramnath, telephone: (703) 292-4776, email: rramnath@nsf.gov
- Gurdip Singh, telephone: (703) 292-8061, email: gsingh@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.

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 provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See Grant Proposal Guide Chapter II, Section D.2 for instructions regarding preparation of these types of proposals.

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

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

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

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of

awards, visit the NSF Website at http://www.nsf.gov

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

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

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

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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

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

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

X. APPENDIX

Frequently Asked Questions (FAQs)

1. Question: What is meant by an infrastructure?

   Answer: Infrastructures are defined as networks of systems and processes that function cooperatively 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: Must an infrastructure system 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 16 critical infrastructures (see http://www.dhs.gov/critical-infrastructure-sectors), several of which are the combinations 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;
- computational processes, which include control, data management and computing services considered critical to and interdependent with other physical and digital systems; and
- 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, computation, data and water availability. Proposers are encouraged to define 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 need 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?

   Answer: Cyber-physical systems (CPS) are engineered systems that are built from, and depend upon, the integration of computational algorithms and physical components. CPS include, 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 computing, information or computational 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 social, behavioral and economic sciences component be considered?

   Answer: No

9. What is meant by interdependent infrastructures?

   Answer: 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 systems: 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; and
   - the interdependency of finance and communication: 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. In this case, 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 only?

    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 feed-forward 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 with consideration of their long-term resiliency. The reduction in service levels or the degradation of process performance due to failures that occur

due to interdependencies and cascading failures is of interest.

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 within scope. Proposals that consider how deliberate attacks exploit cascading failure mechanisms are encouraged. Design strategies that increase system resiliency to all kinds of disturbances, malicious or natural, are within scope.

14. Question: How do PI teams meet “the interdisciplinary criterion” and how do proposals “broadly integrate across engineering, computer, information and computational science, and the social, behavioral and economic (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. In order to ensure an interdisciplinary approach to studying ICIs, proposals should include and clearly identify at least one PI or co-PI who is a computer, information or computational scientist, at least one who is an engineer, and at least one who is a social, economic or behavioral scientist. The solicitation will support teams of three or more PI/co-PIs. Single-PI proposals are not allowed. It is required that the PIs form an interdisciplinary team, but it is not required that they have specific departmental or school affiliations or degrees.

15. Question: In “supplementary documents” under the "management and integration plan", point (d), the PIs are asked to "describe collaborations and partnerships and their integration with the project," what are collaborations and partnerships in this context?

    Answer: This refers both to the collaborations that are formally defined by the submission of collaborative proposals and partnerships with other organizations that are essential to the success of the project. This includes any partners that are receiving funds through any line in the NSF budget. The reasons for their funding should be included in the budget justification document. It also includes partners for whom you have submitted letters of collaboration as part of the supplementary documentation, even if they are not receiving funds from NSF as part of the project.

16. 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.