NSF/VMware Partnership on Edge Computing Data Infrastructure (ECDI)

PROGRAM SOLICITATION
NSF 18-540

National Science Foundation

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

VMware, Inc.

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

  May 22, 2018

IMPORTANT INFORMATION AND REVISION NOTES

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 18-1), which is effective for proposals submitted, or due, on or after January 29, 2018.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

  NSF/VMware Partnership on Edge Computing Data Infrastructure (ECDI)

Synopsis of Program:

  The proliferation of mobile and Internet-of-Things (IoT) devices, and their pervasiveness across nearly every sphere of our society, continues to raise questions about the architectures that organize tomorrow's compute infrastructure. At the heart of this trend is the data that will be generated as myriad devices and application services operate simultaneously to digitize a complex domain like a smart building or smart industrial facility. A key shift is from edge devices consuming data produced in the cloud to edge devices being a voluminous producer of data. This shift reopens a broad variety of system-level research questions concerning data placement, movement, processing and sharing. Importantly, the shift also opens the door to compelling new applications with significant industrial and societal impact in domains such as healthcare, manufacturing, transportation, public safety, energy, buildings, and telecommunications.

  Edge computing is broadly defined as a networked systems architectural approach in which compute and storage resources are placed at the network edge, in proximity to the mobile and IoT devices. The approach offers advantages, such as improved scalability as local computation reduces the volume of data transported, reduced network latency and faster compute response times as data is processed on local compute nodes, and arguably improved security and privacy where data requirements preclude access and exchanges beyond the edge. Edge computing infrastructure may consist of IoT gateways, telephone central offices, cloudlets, micro data centers, or any number of schemes that support the provisioning of communication, compute and storage resources near edge devices.

  This solicitation seeks to advance the state of the art in end-to-end networked systems architecture that includes edge infrastructures. The central challenge is to design and develop data-centric edge architectures, programming paradigms, runtime environments, and data sharing frameworks that will enable compelling new applications and fully realize the opportunity of big data in tomorrow's mobile and IoT device environments. Researchers are expected to carefully consider the implications of edge computing's multi-stakeholder context, and the need for security and privacy as first order design and operational considerations.

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.

- Darleen L. Fisher, Program Director, CISE/CNS, telephone: (703) 292-8950, email: dlfisher@nsf.gov

- Jack Brassil, Program Director, CISE/CNS, telephone: (703) 292-8950, email: jbrassil@nsf.gov

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

- Mimi McClure, Program Director, CISE/CNS, telephone: (703) 292-5197, email: mmcclure@nsf.gov

- J. Christopher Ramming, VMware, telephone: (650) 427-5000, email: chrisramming@vmware.com

- David Ott, VMware, telephone: (650) 427-5816, email: dott@vmware.com

- Sujata Banerjee, VMware, telephone: (650) 427-1066, email: sujatab@vmware.com

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

- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award:

Standard Grant or Continuing Grant or VMware Agreement (Contract or Grant) through VMware or its Vanguard-managed University Research Fund

Estimated Number of Awards: 2

Approximately two awards are anticipated, each up to $3,000,000 total and of 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: $6,000,000

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

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

Limit on Number of Proposals per PI or Co-PI: 1

An individual may participate as PI, co-PI, or senior personnel in **no more than one proposal** submitted in response to this solicitation. In the event that an individual exceeds this limit, the first proposal received within the limit will be accepted based on the earliest date and time of proposal submission (i.e., the first proposal received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

This limit on the number of proposals per PI, co-PI, or senior personnel applies only to this NSF/VMware ECDI program solicitation.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not required

- **Preliminary Proposal Submission:** Not required

- **Full Proposals:**

    - Full Proposals submitted via FastLane: *NSF Proposal and Award Policies and Procedures Guide* (PAPPG) guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.
    - Full Proposals submitted via Grants.gov: *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov* guidelines apply (Note: The *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide).

B. Budgetary Information

- **Cost Sharing Requirements:**

    Inclusion of voluntary committed cost sharing is prohibited.

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

    Not Applicable

- **Other Budgetary Limitations:**

    Not Applicable

C. Due Dates

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

    May 22, 2018

Proposal Review Information Criteria

Merit Review Criteria:

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

Award Administration Information

Award Conditions:

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

Reporting Requirements:

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

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I. INTRODUCTION

The increased proliferation of mobile and IoT devices is touching nearly every sphere of our society. Importantly, this proliferation opens the door to compelling new applications enabled by a combination of edge computing, edge-generated data, and recent advances in data analytics. Sensors, actuators, controllers, industrial devices, and consumer devices are rapidly transforming traditional industries into their "smart", "intelligent", or "digitized" counterparts that are highly connected and exploit computing and communication technology to better program and instrument previously static domains. Many well-known domains that are undergoing transformation include healthcare, manufacturing, transportation, public safety, energy, buildings, and telecommunications.

Edge computing is broadly defined as a networked systems architectural approach for enabling edge applications with special requirements (e.g., low latency, resilience, or confidentiality) in which compute and storage resources are placed at the network edge, in proximity to the mobile and IoT devices. The approach is sometimes described as a three-tier architecture where some infrastructure (sometimes called "edge cloud") is interposed between edge devices and centralized cloud or data center infrastructures. The edge communication and computing infrastructure, which resides in proximity to edge devices, comprises elements--such as IoT gateways, storage facilities, cloudlets or micro data centers--organized according to any of a number of schemes that support the provisioning of communication, compute and storage resources near the edge.

At the heart of this edge computing trend is the data that will be generated as myriad devices and application services operate simultaneously to digitize and dynamically control a complex domain like a smart building or industrial facility. These vast amounts of data will be generated by people, machines, and things. This represents an ongoing shift from edge devices consuming data produced in the cloud, to edge devices being a voluminous producer of data. A single "smart building," for example, may produce as much as several hundreds of gigabytes of data per day.

Data at the edge of the network and within IoT environments may often have a distinct set of attributes compared to enterprise-based, Web-based, or user-based data. Some of these characteristics include:

- The large data volume generated by edge devices (e.g., clustered video monitoring) often precludes transport to the cloud for processing using traditional paradigms.
- Data utility may depend on short time scales. In particular, applications that employ real-time decision-making require low-latency operations, especially where interaction with the physical world is involved (e.g., autonomous cars).
- Data may be noisy or redundant, and may need filtering, aggregation, or abstraction to be useful (e.g., frequent sampling rates, large sensor deployments). The lifecycle of edge data, spanning creation, communication, processing/transformation, archival, and removal may vary across services, and needs careful management with resource constraints in mind.
- Edge data are often consumed directly by other edge devices and local control algorithms.
- Data may need to stay in the edge environment due to privacy, security, and/or regulatory constraints.
- Edge data are increasingly multi-modal (audio, video, log, transducer output, etc.), may be consumed by multiple applications, and have varying levels of importance, depending on the service consuming the data. (For example, unchanging background video is typically of less interest than video depicting activity in the foreground; control and management data to manage the edge infrastructure need priority handling to ensure service level objectives are met.)

Beyond the new data requirements, an important feature of edge computing infrastructure is support for multi-tenancy. While an extensive body of research already exists exploring IoT data challenges, solutions are typically siloed and address only single application environments. Edge computing, in many ways, is about architectures that consider the interests of all stakeholders, ranging from device manufacturers and infrastructure providers (e.g., computing, networking, storage) to application providers and end users. Typically, a single piece of infrastructure (e.g., a mobile device, network, datacenter) may host multiple applications, each of which may have multiple stakeholders (e.g., service owner/operator, end user). The term "multi-tenant" is used to refer to the situation where the infrastructure is multiplexed among multiple applications, regardless of stakeholders. The term "multi-stakeholder" is used to refer to the fact that applications/services operate for the benefit of multiple parties. The basic thesis is that data-focused architectures supporting a rich notion of multi-tenancy and multiple stakeholders can enable a broader service ecosystem.

With multiple stakeholders, an important question to address is if and how data should be shared. Clearly, there will be tradeoffs between maintaining the privacy of data, and the added value obtained by sharing information with another stakeholder. While today's implementation and deployment tend to be siloed, resulting in data and infrastructure redundancies across tenants, an architecture with mechanisms to securely share data at varying granularities should bring down the costs of IoT deployments and improve efficiency in edge environments. Moreover, data sharing could enable richer, more interesting services and interactions between service providers.

A number of frameworks have been developed for managing multi-stakeholder environments. The EdgeX Foundry Project under the Linux Foundation [1] is a vendor-neutral, open source software platform providing a common framework for Industrial IoT edge computing. OpenFog [2] provides a system-level horizontal architecture that distributes resources and services of computing, storage, control and networking across edge infrastructure that lies between clouds and the end devices. The Open Edge Computing [3] initiative makes mobile computing infrastructure a platform for edge computing architecture. While each represents a substantial contribution to the edge computing paradigm, the complexity of data-centric, multi-tenant edge computing architectures as described above needs a more targeted research effort within a broad technical space, and justifies additional effort by the research community.

Overall, edge computing holds the promise of solving many of the hurdles listed above (scalability, latency, etc.) for the future of services and applications that leverage mobile and IoT devices. Moreover, edge computing may help address data privacy and data

sharing issues in settings where data need not be transmitted beyond the edge and shared with only the stakeholders, or where policy mechanisms must be applied immediately within the processing pipeline. Finally, controlled data sharing can make possible new applications enabled by a combination of edge computing, edge-generated data, and recent advances in data analytics.

This solicitation seeks to advance the state of the art in edge computing by focusing on data-centric, multi-tenant edge computing architectures and the associated algorithms for data management and curation.

II. PROGRAM DESCRIPTION

The central challenge to be addressed in this research program is as follows:

What data-centric, multi-tenant edge architectures, programming paradigms, runtime environments, and data sharing approaches will enable compelling new applications and fully realize the opportunity of big data in tomorrow's mobile and IoT device environments?

Researchers must take into account the multi-stakeholder context of future edge computing environments that enable service and device interaction, the controlled exchange of data, and extensible ("open") architectures for a rich, multi-tenant ecosystem of hardware and software. Proposals are, furthermore, expected to address the need for security and privacy as a first order design and operational consideration, and a subset of the key data requirements and characteristics listed above. Furthermore, researching novel services and applications that leverage these new data-centric multi-tenant edge architectures is desirable, though not necessary in every proposal.

Research vectors below offer several potential key areas of work, but are not meant to be prescriptive or to limit the nature and scope of proposed approaches. Researchers should feel free to propose solutions that address broader edge computing challenges in novel and innovative ways.

Vector 1: System Architecture

- **Movement of computation and data.** How might edge computing architectures be constructed to enable flexible and dynamic mechanisms for moving the computation to the data or vice versa, and determining which is most appropriate (even at runtime)? What algorithms can be used to decide the location of data and computation, and what metrics might drive optimization (e.g., latency, bandwidth, energy, cost) for a given architecture?
- **Networking and storage architecture.** What is the proposed networking and storage architecture? How does it enable the movement and management of data and computation? How does it handle high-priority control data within the architecture? How does it address latency and throughput requirements of edge applications? How does it securely connect services to data?
- **Virtualization.** How might virtualization be used to provide flexibility in where computation occurs, and thus enable transparent workload migration, support location-independent application deployment schemes, and provide other benefits?
- **Infrastructure heterogeneity.** How will the system architecture address the problem of infrastructure heterogeneity? Are there unifying abstractions that can simplify interfaces and integration?
- **Edge operating system (OS).** What might an edge computing OS offer? Is one needed and what new attributes beyond existing efforts such as EdgeX [1], Open Edge Computing [3], etc. are needed to support a data-centric, multi-tenant architecture?
- **System abstractions.** What are the right system abstractions for edge-computing data and compute challenges? How might novel abstractions enable compute pipelining and composition, support data sharing and multi-tenancy, and provide useful paradigms for edge-specific applications?

Vector 2: Programming Paradigms

- **Programming abstractions.** What are the right programming paradigms for specifying the management of the infrastructure and movement of data to realize the promised benefits of edge computing?
- **Data curation.** What are the right abstractions for edge-specific data types and characteristics (e.g., streamed data, time series data, aggregated vs. unaggregated data, noisy vs. filtered data, real-time control data, privacy-sensitive data, and so on)?
- **Division of computation.** How does the programming paradigm address the division of computation between edge computing infrastructure and (remote) cloud infrastructure, and between edge computing infrastructure and devices? How does one develop, test, and deploy such applications?
- **Multi-stakeholder.** How does the programming paradigm address multi-tenancy, service interaction, and infrastructure sharing across multiple stakeholders?

Vector 3: Security, Privacy, and Data sharing

- **Location-independent data sharing.** How does controlled data sharing between services and devices work within the multi-stakeholder, multi-location context of applications that take advantage of edge computing infrastructure?
- **Isolation.** What mechanisms ensure data isolation within the shared, multi-tenant architecture? How might virtualization approaches be used to achieve isolation in shared computation and storage infrastructure?
- **Heterogeneous data types.** How will security and privacy mechanisms address different types of data within the edge cluster? For example, how will control information be secured and securely transmitted across the edge infrastructure?
- **Architecture and programming models.** How do security and privacy figure into edge computing architectures and programming paradigms as first order considerations?

A note on side channel security research: While mitigation of side channel vulnerabilities within multi-tenant compute and storage infrastructure is obviously an important issue, researchers should not submit proposals that feature it as a principal area of investigation.

Researchers are expected to develop prototypes of their proposed approaches to explore implementation aspects of their designs and to demonstrate the effectiveness of their approaches empirically. Prototypes should leverage existing software tools and frameworks where possible, and avoid unnecessary re-invention. Some notable multi-tenancy frameworks include VM-based cloudlets, EdgeX Foundry from the Linux Foundation, and Open Edge Computing [3]. Having said that, researchers are welcome to develop new software frameworks whenever required by their investigations. Proposals should explain the gap and justify the need for developing something entirely new.

Researchers are encouraged to use existing testbeds for deploying and testing prototypes of their work, and for collecting data to demonstrate the effectiveness of their approach. Such testbeds include but are not limited to:

- Global Environment for Network Innovations (GENI) [4]; and
- NSFFutureCloud [5] with projects Chameleon [6] and CloudLab [7].

Evaluation Plan

Proposers are expected to develop an evaluation plan that helps validate the benefits of the research and drive progress in desirable directions (including metrics where appropriate).

Potential Application Domains

Researchers should anchor their work in one or more application domains of societal relevance, considering the intersection of multiple industries and service providers. In the domain(s) of interest, focus must be on data and multi-tenancy aspects. Illustrative examples include but are not limited to those listed below. Each domain listed below is rich with multi-modal data with multiple stakeholders and a variety of real-time and non-real-time management and control requirements. Researchers are encouraged to propose and develop novel applications or services that uniquely benefit from data-centric edge computing architectures.

- **Intelligent Transportation.** There are longstanding goals regarding the deployment of edge infrastructure (vehicle-to-infrastructure and vehicle-to-vehicle) in support of safety and increased energy efficiency. The deployment of this edge infrastructure can be overwhelming in the context of any single application; of interest would be solutions that allow the cost and usage of that edge infrastructure to be shared between the public sector and private sector, with overall value that is increased by the controlled sharing of information across application silos. The tension between privacy and added value from information sharing complicates and further inhibits adoption. How could the ideas proposed to this solicitation unblock progress?
- **Smart Cities and Communities.** Many cities are interested in deploying edge infrastructure (with basic city-wide WiFi being the canonical, and perhaps simplest, example of such infrastructure). What novel services (safety, community policing, citizen) could be supported with more sophisticated edge infrastructure and what would be the interactions between relevant data streams and supporting organizations (fire, police, utilities, private companies, end users)? What kinds of architectures will support the controlled sharing of appropriate information with appropriate transparency, confidentiality, provenance, and access control?
- **5G and Beyond Telecommunications.** The global telecommunications industry is exploring ways of increasing capacity by orders of magnitude, while reducing latency and supporting a richer array of end-user services (including IoT). Edge infrastructure to support content/compute distribution networks represent one way to scale the existing network toward the requirements of IoT and emerging services, but also represent a significant expense. How could that expense be monetized or shared by making the edge infrastructure multi-tenant and multi-user? What kinds of provisioning and administrative interfaces should the telecom providers offer to the users of that edge infrastructure, what would be the impact of such offerings, and what kinds of isolation guarantees could be provided on the part of service providers?
- **Industrial IoT.** In the context of the industrial IoT (smart buildings, factory automation, infrastructure optimization, etc.), "edge infrastructure" manifests in the form of a "gateway" that serves as an aggregation point for IoT device data streams, and as a local point of control for IoT applications. Multi-tenancy could potentially reduce the deployment and operation costs of such gateways, if there were means to ensure performance and security isolation. Numerous variations on gateway ownership and management responsibility also exist. Should the owner of the infrastructure permit the hosting of service silos? Could a service provider (e.g., cable company or utility) deploying the gateway recoup its expenses by hosting other service providers? Who has rights to control (or even have visibility into) the data that are produced and consumed by devices attached to the gateway?

Expectations Concerning End-of-Program Results and Plans for Broader Impacts

This solicitation seeks to advance the deployment of successful three-tiered architectures by exploring data-centricity and multi-tenancy in emerging edge infrastructure. Potential program results include theories, algorithms, architectures, prototypes of system components, prototypes of applications, testbeds, and evaluations. Robust, production-level code is neither expected nor encouraged, nor is the complete end-to-end integration of all research results; having said that, clear planned synergies between sub-efforts is desirable. Proposers should strive to be concrete about any plans to achieve broader impacts with any foundational results (e.g., open source releases as a means of building community and experimentation, or testbeds that encourage participation in nascent multi-tenant deployments in relevant domains).

Developing solutions in the context of a specific application domain such as described above is highly encouraged, with extrapolations of results to other domains. Proposers should build lean, well-integrated teams of researchers with expertise in all areas necessary to conduct the proposed work. The appropriateness of a given research team's composition and expertise should be justified with respect to the focused goals of the project, and will be a factor in evaluating the merit of the proposal (see Additional Solicitation Specific Review Criteria below).

NSF and VMware will support multiple projects with total budgets of up to $3,000,000 each for durations of up to three years, and it is intended that NSF and VMware will co-fund each project. If successful, proposed research projects should have the potential to fundamentally improve the capabilities of edge computing data infrastructures. Towards this end, VMware may contribute open-source software and expertise related to ECDI to the program awardees.

[1] EdgeX Foundry: https://www.edgexfoundry.org

[2] OpenFog Consortium Architecture Working Group: http://www.OpenFogConsortium.org

[3] Open Edge Computing: http://openedgecomputing.org

[4] Global Environment for Network Innovations: http://www.geni.net

[5] NSFFutureCloud: https://nsf.gov/news/news_summ.jsp?cntn_id=132377

[6] Chameleon: www.chameleoncloud.org

[7] CloudLab: https://cloudlab.us

III. AWARD INFORMATION

Anticipated Type of Award: Continuing Grant or Standard Grant or VMware Agreement (Contract or Grant) through VMware or its Vanguard-managed University Research Fund

Estimated Number of Awards: 2

Approximately two awards are anticipated, each up to $3,000,000 total and of 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: $6,000,000, subject to the quality of proposals received and availability of funds.

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

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Institutions of Higher Education (IHEs) - Two- and four-year IHEs (including community colleges) accredited in, and having a campus located in the US, acting on behalf of their faculty members. Special Instructions for International Branch Campuses of US IHEs: If the proposal includes funding to be provided to an international branch campus of a US institution of higher education (including through use of subawards and consultant arrangements), the proposer must explain the benefit(s) to the project of performance at the international branch campus, and justify why the project activities cannot be performed at the US campus.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

Limit on Number of Proposals per PI or Co-PI: 1

An individual may participate as PI, co-PI, or senior personnel in **no more than one proposal** submitted in response to this solicitation. In the event that an individual exceeds this limit, the first proposal received within the limit will be accepted based on the earliest date and time of proposal submission (i.e., the first proposal received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

This limit on the number of proposals per PI, co-PI, or senior personnel applies only to this NSF/VMware ECDI program solicitation.

Additional Eligibility Info:

Subawardees may only include two-and four-year IHEs (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members.

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Full Proposal Preparation Instructions: Proposers may opt to submit proposals in response to this Program Solicitation via Grants.gov or via the NSF FastLane system.

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg. Paper copies of the PAPPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.

- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov*. The complete text of the *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: (https://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

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

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via the NSF FastLane system. PAPPG Chapter II.D.3 provides additional information on collaborative proposals.

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

Proposal Titles:

A proposal title must begin with "ECDI:". For example, titles should take the form **ECDI: Title**. If you submit a proposal as part of a set of collaborative proposals, the title of the proposal should begin with "ECDI:" followed by "Collaborative Research:", followed by the title. For example, if you are submitting a collaborative set of proposals, the title of each would be **ECDI: Collaborative Research: Title**.

Project Description:

Describe the research and education activities to be undertaken in **up to 20 pages**. Note that additional documents listed under the Single Copy Documents and Supplementary Documents sections below do not count towards this page limit. All proposals are expected to:

- Describe how the project goals and research and education outcomes have the potential to fundamentally improve the capabilities of edge computing data infrastructures;
- Clearly explain the research component(s) of the project;
- Explain how research outcomes can be generalized to other areas of application;
- Explain how the proposed research aligns with the Program Description;
- Present a plan to integrate research outcomes into education and more broadly advance education in the field;
- Include a plan for validation of the research by experimentation and prototyping;
- Provide plans for disseminating the research and education outcomes in a manner that enables the research community to use the results in ways that go beyond traditional academic publications;
- If the proposal involves a collaboration spanning multiple institutions, provide a compelling rationale for the multi-institution structure of the project and an explanation of how effective collaboration will be assured; and
- Present a research plan including a **Gantt chart** with major tasks, milestones, and interdependencies.

For all collaborative projects, Project Descriptions must be comprehensive and well-integrated, and should make a convincing case that the collaborative contributions of the project team will be greater than the sum of each of their individual contributions.

Supplementary Documents:

In the Supplementary Documents section, upload the following information where relevant or required.

1. *A list of Project Personnel and Partner Institutions (required):*

   Note: In collaborative proposals, the lead institution should provide this information for all participants):

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

   - Mary Smith; XYZ University; PI
   - John Jones; University of PQR; Senior Personnel
   - Jane Brown; XYZ University; Postdoc
   - Bob Adams; ABC Community College; Paid Consultant
   - Susan White; Welldone Institution; Unpaid Collaborator
   - Tim Green; ZZZ University; Subawardee

2. *Collaboration Plan (if applicable):*

Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, a substantive Collaboration Plan is required for all proposals with more than one investigator. Up to 2 pages are allowed for Collaboration Plans. The length of and level of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. The appropriateness of the research team's composition and expertise should be justified with respect to the focused goals of the project, and will be a factor in the merit review. Where appropriate, the Collaboration Plan should include: 1) the specific roles of the project participants in all organizations involved; 2) information on how the project will be managed across all the investigators, institutions, and/or disciplines; 3) identification of the specific coordination mechanisms that will enable cross-investigator, cross-institution, and/or cross-discipline scientific integration (e.g., yearly workshops, graduate student exchange, project meetings at conferences, use of video-conferences, software repositories, etc.); and 4) specific references to the budget line items that support collaboration and coordination mechanisms. The Collaboration Plan should reference and support the project research plan, including key interdependencies between tasks for different PIs, outlined in the Project Description. However, note that the Collaboration Plan should not be used to expand discussions on proposed research activities; all research activities should reside within the Project Description section.

If a proposal with more than one investigator does not include a Collaboration Plan of at most 2 pages, that proposal will be returned without review.

3. *Postdoctoral Researcher Mentoring Plan (if applicable):*

Each proposal that requests funding to support postdoctoral researchers must include, as a supplementary document, a description of the mentoring activities that will be provided for such individuals. In no more than one page, the mentoring plan must describe the mentoring that will be provided to all postdoctoral researchers supported by the project, irrespective of whether they reside at the submitting organization, any subawardee organization, or at any organization participating in a simultaneously submitted collaborative project. Please be advised that, if required, FastLane will not permit submission of a proposal that is missing a Postdoctoral Researcher Mentoring Plan. See Chapter II.C.2.j of the PAPPG for further information about the implementation of this requirement.

4. *Data Management Plan (required):*

Proposals must include a supplementary document of no more than two pages labeled "Data Management Plan." This supplementary document should describe how the proposal will conform to NSF policy on the dissemination and sharing of research results and the intellectual property, publishing, and licensing requirements outlined under the Special Award Conditions section below.

See Chapter II.C.2.j of the PAPPG for full policy implementation.

For additional information see: https://www.nsf.gov/bfa/dias/policy/dmp.jsp.

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

Single Copy Documents:

Collaborators and Other Affiliations Information: Proposers should follow the guidance specified in Chapter II.C.1.e of the NSF PAPPG. Grants.gov Users: The COA information must be provided through use of the COA template and uploaded as a PDF attachment.

Note the distinction to the list of Project Personnel and Partner Institutions specified above under Supplementary Documents: the listing of all project participants is collected by the project lead and entered as a Supplementary Document, which is then automatically included with all proposals in a project. The Collaborators and Other Affiliations are entered for each participant within each proposal and, as Single Copy Documents, are available only to NSF staff.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Budget Preparation Instructions:

Budgets for projects should include funding for one or more project representatives (PI/co-PI/senior researcher or NSF-approved replacement and key students or postdocs) to attend a kickoff meeting as well as annual retreats held during the proposed lifetime of the award. For budget preparation purposes, PIs should assume these meetings will be held each year at VMware's corporate headquarters in Palo Alto, CA.

The budget submitted with the proposal should include all necessary project funds without regard to the two funding organizations; NSF and VMware will inform selected PIs of the breakdown in funding between the two organizations, and will request revised budgets at that point.

C. Due Dates

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

D. FastLane/Grants.gov Requirements

For Proposals Submitted Via FastLane:

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

For Proposals Submitted Via Grants.gov:

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

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

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

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

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

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

Proposers should also be aware of core strategies that are essential to the fulfillment of NSF's mission, as articulated in *Building the Future: Investing in Discovery and Innovation - NSF Strategic Plan for Fiscal Years (FY) 2018 – 2022*. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

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

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

A. Merit Review Principles and Criteria

The National Science Foundation strives to invest in a robust and diverse portfolio of projects that creates new knowledge and enables

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

1. Merit Review Principles

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

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

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

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

2. Merit Review Criteria

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

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

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

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

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

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

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

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

Additional Solicitation Specific Review Criteria

NSF engages in partnership programs with companies in order to increase the potential for research discoveries to translate into innovations with societal impact through market mechanisms. It also seeks to foster insights that arise at disciplinary boundaries. While

all aspects of Intellectual Merit and Broader Impacts described above will be considered, special attention will be placed on the degree to which:

- Project plans pursue both the development of a systems perspective as well as the creation, deployment, and evaluation of demonstrations or prototypes at the component and eventually the system levels;
- Proposals include lean, well-integrated teams of researchers with expertise in critical area(s) necessary to conduct the proposed work;
- Projects demonstrate concrete plans to impact and influence the broader industry; and
- Researchers use existing components and infrastructure including multi-tenant edge computing software frameworks such as EdgeX, Open Edge Computing, Cloudlets and existing research testbeds such as CloudLab, GENI, etc., and provide justification for their choices. Note: if proposing to build a new framework, justification is needed for why existing frameworks do not suffice.

B. Review and Selection Process

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

A uniform review process will be conducted by NSF for all proposals received responding to this program solicitation. VMware may, through designated VMware Program Directors, provide input on the selection of reviewers and attend any review panels, including Reverse Site Visits, as observers. Upon conclusion of the review, award recommendations will be coordinated by a Joint NSF and VMware Working Group (hereafter referred to as JWG) comprising Program Directors from both NSF and VMware. Review materials from the NSF merit review process (i.e., proposals, unattributed reviews, and panel summaries) will be shared with appropriate VMware personnel for purposes of their review, as well as for subsequent discussion by the JWG. Additionally, if a given partnership award is deemed to fit the characteristics of a charitable contribution, VMware may recommend that its donor-advised fund at Vanguard Charitable make the award. In this case, the same review materials for the recommended proposal may be shared with Vanguard Charitable personnel for the purposes of performing their due diligence. All such information shared between NSF, VMware, and Vanguard Charitable will be kept confidential.

NSF Review Process

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

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

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

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

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

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

B. Award Conditions

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

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

More comprehensive information on NSF Award Conditions and other important information on the administration of NSF awards is contained in the NSF *Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

Special Award Conditions:

1. **Site visits, meetings, and annual retreats**

   VMware and NSF will organize annual retreats for awardees that will bring together the academic community involved in a specific NSF/VMware Partnership program, along with NSF and VMware personnel who have interest in that program. VMware and NSF will work with academic leadership to organize these events. VMware will provide space for such meetings at its corporate headquarters in Palo Alto, CA. They will involve reviews of the research underway in each project along with presentations from NSF and VMware on technical areas of interest related to each awarded project. Ample time will be provided for face-to-face interaction between participants in these retreats. NSF views these meetings as fundamentally valuable opportunities for faculty and students to learn about industry trends and context, and thereby to increase the potential for transitioning research results to practice.

2. **Intellectual property, publishing, and licensing**

   NSF/VMware Partnership awardees will agree to dedicate to the public all intellectual property resulting from the research funded as part of this program, and further:

   - The awardees will, with respect to software, offer such software through an open source license under an Apache 2.0 license found at: http://www.opensource.org/licenses/apache2.0.php or other similar open source license; in the event the software already contains code licensed under GNU's General Public License (GPL), then the open source shall be through GPL version 3 found at http://www.gnu.org/licenses/gpl.html;
   - The awardees will submit for publication in openly available literature any results of the research funded as part of this program that are deemed to meet the standards for research publications in the field of study; and
   - The awardees will deposit all published manuscripts and juried conference papers in a public access-compliant repository in accordance with the guidelines set forth in NSF's Public Access Policy (see NSF Public Access Frequently Asked Questions at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf18041&org=NSF) no later than 12 months after initial publication.

   Awardees will be required to include appropriate acknowledgment of NSF and VMware support in reports and/or publications on work performed under the award. An example of such an acknowledgement would be: "This material is based upon work supported by the NSF/VMware Partnership on Edge Computing Data Infrastructure (ECDI) program under Award Title and No. [Recipient enters project title and awards number(s)]." If VMware recommends funding through its donor-advised fund at Vanguard Charitable and such funding is granted, awardees will provide recognition to the VMware University Research Fund.

3. **VMware participation in research**

   Upon request from the award recipient, or from NSF with the recipient's consent, VMware will share industry context, insights, and experience with the award recipient in order to support the success of the funded academic researchers. VMware may separately fund its own personnel to directly support the NSF/VMware Partnership research, part-time or full-time, with the institutions awarded NSF/VMware Partnership projects. Proposals do not need to budget for the cost of such personnel. At the request of an award recipient, or at the request of NSF with the recipient's consent, VMware researchers may work alongside the academic researchers on related projects, may be involved with the projects as advisors, and may be in a position to host student interns who wish to gain further industry experience. Further, at the request of an award recipient, or of NSF with the recipient's consent, VMware may designate one of its more senior, separately-funded researchers or engineers to work alongside NSF/VMware Partnership academic lead PIs to help identify promising directions for increased industrial and societal impact.

   Such personnel will be available to the academic researchers solely for the benefit of the academic researchers and will not attempt to control or direct the research. To the extent that VMware personnel provide expertise at the request of an award recipient, such expertise should be understood as advice to the award recipients and the PIs, and shall not be understood either as advice to NSF or as compulsory for the award recipients and PIs. VMware will not seek any information that the researchers do not intend to share widely with other parties. VMware may provide the researchers with software (prototypes or products), computing infrastructure, or other support related to its products or internal research; however, in no case will any researcher be required to use VMware's offered contributions.

4. **Program management**

   NSF and VMware will each designate a Program Director for each NSF/VMware Partnership award who will jointly oversee the execution of the project. The VMware Program Director may become a member of the NSF/VMware Partnership Project Management Team. Upon the request of an award recipient, or of NSF with the consent of the recipient, in order to help advise researchers on technical issues and industry context, VMware will be granted access to any reports or meetings

normally required by NSF.

Annual on-site reviews may be conducted jointly by NSF and VMware. VMware will not be expected to share proprietary information, and neither will VMware presentations be published more broadly without explicit consent. Materials presented by the academic researchers at these meetings will be public material, as allowed by law. In order to support the NSF's vision of industry-academic interaction leading to greater impact for NSF-funded research, at the request of an award recipient, or of NSF with the recipient's consent, VMware may lead the organization of biannual or more frequent phone calls with project teams in which NSF will also participate at its discretion. NSF may request visits to the research institutions or may ask PIs to visit NSF or VMware. Institutions may request site visits to VMware or invite site visits from VMware. VMware may invite academic faculty and students to visit VMware and may visit research institutions upon request.

5. **Funding support and budget revisions**

Each awarded project will be jointly funded by NSF and VMware through separate NSF and VMware funding instruments. NSF awards will be made as continuing or standard grants. VMware awards will be made as VMware agreements (Contracts, Grants, or Gifts). If a given partnership award is deemed to fit the characteristics of a charitable contribution, VMware may recommend that Vanguard Charitable make the award. NSF and VMware will manage their respective awards/agreements in accordance with their own guidelines and regulations. Either organization may supplement a project without requiring the other party to provide any additional funds.

The budget submitted with the proposal should include all necessary project funds without regard to the two funding organizations; NSF and VMware will inform selected PIs of the breakdown in funding between the two organizations, and will request revised budgets at that point.

C. Reporting Requirements

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

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

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

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) Chapter VII, available electronically on the NSF Website at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg.

PIs are not required to submit reports to VMware. However, PIs acknowledge that VMware will be granted confidential access to any such reports required by NSF.

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:

- Darleen L. Fisher, Program Director, CISE/CNS, telephone: (703) 292-8950, email: dlfisher@nsf.gov

- Jack Brassil, Program Director, CISE/CNS, telephone: (703) 292-8950, email: jbrassil@nsf.gov

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

- Mimi McClure, Program Director, CISE/CNS, telephone: (703) 292-5197, email: mmcclure@nsf.gov

- J. Christopher Ramming, VMware, telephone: (650) 427-5000, email: chrisramming@vmware.com

- David Ott, VMware, telephone: (650) 427-5816, email: dott@vmware.com

- Sujata Banerjee, VMware, telephone: (650) 427-1066, email: sujatab@vmware.com

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 VMware Research & Innovation
>
> VMware Research & Innovation delivers breakthrough technologies to fuel the growth and productivity of the computing industry as well as VMware's technology leadership. VMware focuses its research in the areas of software and distributed systems, with particular emphasis on virtualization in all aspects (e.g., compute, storage, and network) as well as systems management. VMware comprises R&D centers in many countries.
>
> VMware Research & Innovation works with industry partners, government, and academia throughout the world to advance the state of the art in computing. VMware also supports groundbreaking university research projects through the VMware University Research Fund.

ABOUT THE NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) is an independent Federal agency created by the National Science Foundation Act of 1950, as amended (42 USC 1861-75). The Act states the purpose of the NSF is "to promote the progress of science; [and] to advance the national health, prosperity, and welfare by supporting research and education in all fields of science and engineering."

NSF funds research and education in most fields of science and engineering. It does this through grants and cooperative agreements to more than 2,000 colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations throughout the US. The Foundation accounts for about one-fourth of Federal support to academic institutions for basic research.

NSF receives approximately 55,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded. In addition, the Foundation receives several thousand applications for graduate and postdoctoral fellowships. The agency operates no laboratories itself but does support National Research Centers, user facilities, certain oceanographic vessels and Arctic and Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US participation in international scientific and engineering efforts, and educational activities at every academic level.

Facilitation Awards for Scientists and Engineers with Disabilities (FASED) provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See the *NSF Proposal & Award Policies & Procedures Guide* Chapter II.E.6 for instructions regarding preparation of these types of proposals.

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

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

> The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.
>
> To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at https://www.nsf.gov
>
> - **Location:** 2415 Eisenhower Avenue, Alexandria, VA 22314
>
> - **For General Information** (703) 292-5111
>   (NSF Information Center)**:**
>
> - **TDD (for the hearing-impaired):** (703) 292-5090

- **To Order Publications or Forms:**

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

    or telephone: (703) 292-7827

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

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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

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

Suzanne H. Plimpton
Reports Clearance Officer
Office of the General Counsel
National Science Foundation
Alexandria, VA 22314

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National Science Foundation, 2415 Eisenhower Avenue, Alexandria, Virginia 22314, USA
Tel: (703) 292-5111, FIRS: (800) 877-8339 | TDD: (703) 292-5090 or (800) 281-8749

Text Only

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