Resilient & Intelligent NextG Systems (RINGS)

PROGRAM SOLICITATION
NSF 21-581

National Science Foundation

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

Directorate for Engineering
    Division of Electrical, Communications and Cyber Systems

Department of Defense

Office of the Under Secretary of Defense for Research and Engineering

National Institute of Standards and Technology

Apple

Ericsson

Google

IBM

Intel

Microsoft

Nokia

Qualcomm

vmware VMware

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

> July 29, 2021

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 20-1), which is effective for proposals submitted, or due, on or after June 1, 2020.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

> Resilient & Intelligent NextG Systems (RINGS)

Synopsis of Program:

> The RINGS program seeks to accelerate research in areas that will potentially have significant impact on emerging Next Generation (NextG) wireless and mobile communication, networking, sensing, and computing systems, along with global-scale services, with a focus on greatly improving the resiliency of such networked systems among other performance metrics. Modern communication devices, systems, and networks are expected to support a broad range of critical and essential services, incorporating computation, coordination, and intelligent decision making. Resiliency of such systems, which subsumes security, adaptability, and autonomy, will be a key driving factor for future NextG network systems. Resiliency in both design and operations ensures robust network and computing capabilities that exhibit graceful performance- and service-degradation with rapid adaptability under even extreme operating scenarios. The RINGS program seeks innovations to enhance both resiliency as well as performance across the various aspects of NextG communications, networking and computing systems. This program seeks to go beyond the current research portfolio within the individual participating directorates by simultaneously emphasizing gains in resiliency (through security, adaptability and/or autonomy) across all layers of the networking protocol and computation stacks as well as in throughput, latency, and connection density.

> In this program, NSF is partnering with the Office of the Under Secretary of Defense for Research and Engineering (OUSD R&E), the National Institute of Standards and Technology (NIST) and a number of industry partners shown above. This program seeks to fund collaborative team research that transcends the traditional boundaries of individual disciplines to achieve the program goals.

> **SELECTED LIST OF ACRONYMS**

> AI - Artificial Intelligence

> AR - Augmented Reality

> Gbps - Giga-bit per second.

> IoT - Internet of Things

> MHz - MegaHertz

> MIMO - Multiple-Input and Multiple-Output

> ms - Millisecond

> NextG - Next Generation Wireless Broadband Networks

> PAWR - Platform on Advanced Wireless Research

> RF - Radio Frequency

> RV - Research Vector

THz - TeraHertz

UAS - Unmanned Aircraft Systems

VR - Virtual Reality

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.

- Alexander Sprintson, CISE/CNS, telephone: (703) 292-8950, email: asprints@nsf.gov
- Murat Torlak, CISE/CNS, telephone: (703) 292-7748, email: mtorlak@nsf.gov
- Mohammod Ali, ENG/ECCS, telephone: (703) 292-4632, email: moali@nsf.gov
- Erik Brunvand, CISE/CNS, telephone: (703) 292-8950, email: ebrunvan@nsf.gov
- Phillip A. Regalia, CISE/CCF, telephone: (703) 292-2981, email: pregalia@nsf.gov
- Zhengdao Wang, ENG/ECCS, telephone: (703) 292-7823, email: zwang@nsf.gov

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

- 47.041 --- Engineering
- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award: Continuing Grant

Estimated Number of Awards: 36 to 48

Approximately 36-48 awards are anticipated, each up to $1,000,000 total and up to 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: $37,500,000 to $40,000,000

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

The budget should be commensurate with the scope of the proposed research.

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:

By the submission deadline, any PI, co-PI, or other senior project personnel must hold either:

- a tenured or tenure-track position, or
- a primary, full-time, paid appointment in a research or teaching position

at a U.S.-based campus of an institution eligible to submit to this solicitation (see above), with exceptions granted for family or medical leave, as determined by the submitting institution. Individuals with primary appointments at for-profit non-academic organizations, non-profit non-academic organizations, or at overseas branch campuses of U.S. IHEs are not eligible.

Researchers from foreign academic institutions who contribute essential expertise to the project may participate as senior personnel or collaborators but may not receive NSF support.

Guidelines for the Participation of Partner Companies and Affiliated Individuals in Proposals:

Guidelines for Partner Companies:

A partner company is not permitted to participate in proposals to the program.

Guidelines for Individuals Affiliated with Partner Companies:

Individuals affiliated with a partner company may participate in proposals to the program subject to certain limitations and allowances. These limitations and allowances apply to individuals who are currently employed by, consulting for, or on an active agreement to provide services for the company. Specifically:

- Such individuals may not participate in their capacity with the company.
- Such individuals may participate if they (i) hold a primary appointment at another organization not partnered on the

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program (e.g., a primary academic appointment at an institution of higher education), as applicable to and defined by that organization, and (ii) do so strictly in their capacity at that other organization.

Proposals that violate the above restrictions may be returned without review.

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 be listed as PI, co-PI, and/or senior personnel on no more than two proposals submitted in response to this solicitation. In the event that an individual exceeds this limit, only the first two proposals received before the deadline will be accepted, and the remainder 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* (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 Research.gov: *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):

  July 29, 2021

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria. Additional merit review criteria 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

Wireless mobile broadband communication networks have seen rapid development over the last two decades. This growth has brought about new capabilities, including increased data rates, lower latencies, support for more users and improved coverage. Introduction of computational capabilities and services embedded within modern communication networks have changed how we communicate, from a voice-only model of interaction to a multi-modal interaction that incorporates voice, text messages, video, data, computation and data analytics. These networks have become a vital component of our daily lives by supporting reliable communication, ubiquitous computing and data storage resources. These networks are thus an essential part of societal infrastructure, much like power, water, and transportation networks, with growing need for built-in service assurance assumptions of availability, reliability and resiliency.

NextG wireless broadband networks are expected to support features such as per-user throughputs of 1 gigabit-per-second (Gbps) or more, as well as ultra-low access latencies of 1 millisecond (ms) or less for massive numbers of devices and services, enabling exciting new applications such as Augmented Reality/Virtual Reality (AR/VR) and video analytics. These NextG networks will constitute a complex system that leverages technologies such as software-defined networking (SDN), programmable accelerators, network function virtualization (NFV), cloud-computing platforms, dynamic orchestration, and mobile edge computing (MEC), while seeking to deploy artificial intelligence (AI)/machine learning (ML) techniques to enhance autonomous management and operations capabilities. Designing and managing such complex entities requires a system-level mindset, and thus we identify them as "NextG network systems".

NextG network systems (e.g., 6G cellular, future versions of WiFi, satellite networks) are expected to connect billions of heterogeneous Internet of Thing (IoT) devices along with billions of people, enable machine-to-machine communications, and provide low-latency computational and storage resources on-demand at the edge and in the cloud. Using a combination of intelligence and autonomy, such network systems are likely to support a variety of critical and personalized services in multiple application domains, including education, transportation, public health and safety, and defense. The economy will become ever more dependent on the high availability, security and reliability of such network systems. Any failure, tampering or degradation in network service can have highly disruptive, if not potentially catastrophic, effects. Therefore, it is essential that these NextG network systems have high degrees of resiliency at-scale (regardless of complexity), reliability, and availability, with strong expectations on both performance and service assurance, despite any combination of natural or human-induced disruptions. All these features should be able to scale as network and service complexities grow.

Resiliency can be viewed as having several components: security, adaptability, autonomy and reliability. While network designers have always had to balance performance and innovation with reliability and security, today's tools and techniques for network system design do not yet address the resilience of the network in a comprehensive, integrated manner, which has led to a world where factors such as security vulnerabilities, unstable updates and misconfigured systems create unpredictable behaviors. While tolerated in today's networks, these unpredictable behaviors are unacceptable in a NextG network system supporting 'essential and critical services'. In addition, multiple competing interests may be operating on the same network infrastructure, while the underlying hardware and software may be untrusted.

NSF, OUSD R&E, NIST, and multiple industry partners have come together to develop the RINGS program to address this challenge. This program seeks to support research that will lead to resilient NextG network systems, enhancing their security and reliability while advancing the underlying technologies that boost performance to support the communication and computational demands that are expected of such networks over the next two decades. For the purposes of this solicitation, resiliency is the ability to survive, gracefully adapt to, and rapidly recover from malicious attacks, component failures, and natural and human-induced disruptions.

II. PROGRAM DESCRIPTION

NextG network systems will support dynamically varying demands for data processing, dissemination, and storage, often in a distributed user-to-edge-to-cloud continuum context. These network systems are expected to provide personalized and composable services, enable real-time computing/learning capabilities and facilitate large-scale content distribution, underpinned by a high-performance foundation of advanced wireless connectivity and mobility support. They will feature dynamic composition of heterogenous components, systems and fabrics using a microservices architecture. Service providers are looking to offer this kind of mobile infrastructure as a service (e.g., as an end-to-end "slice" of the network system) to various industries such as defense, critical infrastructure, transportation, healthcare, logistics, smart agriculture, finance, and entertainment, each of which will entail a unique set of security, reliability and service assurance requirements.

Providing resiliency guarantees while ensuring cutting-edge performance is an under-explored topic in network systems research. The challenges are well-recognized: geographical spread, distributed attack surfaces, multi-modal failures, unforeseen dependencies across sub-systems leading to cascading failures, etc. For example, the base system components, such as towers, antennas, fiber-optic cables, computing, storage devices, software systems and services are

susceptible to failure during extreme weather events. The NextG network systems are expected to be very complex and include many different components, including IoT devices, user elements, radio heads, backhaul, and edge and cloud servers. The limited/diverse capabilities of such devices and their individual management model make it harder to deploy sophisticated security functions. It is likely that some elements of the system will remain unprotected and highly vulnerable to failures and attacks. With software replacing many functions traditionally done in hardware, additional failure modes might be introduced. Increasing reliance on AI techniques within the network may expose additional attack vulnerabilities. Always relying on a human-in-the-loop control system to rapidly recover from disruptions might be impossible given the scale of network systems and the impact of disruptive events. Providing resilient communication and computation services across this heterogenous and dynamic environment is a significant challenge.

The NextG network system should thus be secure, intelligent and support autonomous decision-making. Recent developments in AI/ML tools and techniques have significant potential for achieving zero-touch "self-managing" mobile broadband networks that include a high degree of operational agility. Autonomy will enable network systems to respond to performance issues and emerging threats by reprogramming and/or reconfiguring themselves upon failures or attacks. Autonomy can also potentially enable zero-trust systems models in the network and thus support strong security properties even in the presence of untrustworthy hardware, software or network operators.

II.1. PROGRAM GOAL AND THEMES

The goal of the RINGS program is to approach the design of NextG network systems from a different perspective by considering resilience as the primary consideration while aiming for superior performance. This program thus complements the current NSF research portfolio that supports basic research in the theory and practice of individual emerging topics, including AI/ML, edge computing, radio communications, innovative transmit/receive technologies, and effective spectrum utilization.

Proposals submitted in response to this program must address one or more research vectors (RV) from each of the two groups listed below. Each proposal should clearly identify the RVs chosen in the text of the project description. The program strongly encourages cross-layer collaboration or teaming to meet the stated goals.

The RVs described below for both Resilient Network Systems (Group A) and Enabling Technologies (Group B) are not arranged in any order of preference and will be given equal consideration. In addition, the specific research topics within each RV are provided only as examples and are not intended to be exhaustive.

Proposals must clearly describe the synergy between RVs chosen in Group A and Group B, i.e. how the proposed technology advances in Group B contribute to commensurate advances in Resiliency attributes – this is an essential requirement of the program.

Group A: RESILIENT NETWORK SYSTEMS

This group addresses the main theme of the project, which is resiliency in the network as well as the associated service and computation architecture. Resiliency can be achieved along multiple dimensions – through ensuring that the network systems are secure from internal and external attacks, through being highly flexible and dynamically adaptive at-scale and over rapid timescales to handle a multitude of large and small disruptions, or through other means. Each proposal should explain how the proposed research will seek to ensure resilient network systems with one or more of the following attributes:

1. Resistance and/or high tolerance to attacks, failures and service disruptions, with rapid identification of the root causes;
2. Graceful degradation of service and rapid adaptability when resource availability is impacted by disruptive events; and/or
3. Resiliency in computational capabilities spread across distributed, heterogeneous, and disaggregated resources.

Proposers must choose **one or more** of the following RVs to demonstrate resilience:

A1: Full Stack Security: An overarching goal of the network system is to provide end-to-end security, without which network applications cannot function in a reliable and predictable manner. NextG network systems will be used to enable and support essential and/or life-critical services. Any interruption in such services may lead to very significant societal consequences. Thus, an important goal for the NextG network systems is to achieve a drastic reduction in attack vectors compared to the current systems. This RV will advance a secure-by-design approach that enables the network designers and architects to eliminate entire categories of threats and address security requirements at the earliest stages of the design process. A secure-by-design approach can be coupled with a clean slate approach to ensure that system architects are not constrained by compatibility requirements with existing systems.

Examples of some research topics include, but are not limited to:

1. Composable and programmable security;
2. Zero-trust security, covering design, operations and management involving untrustworthy components of the network system;
3. Formal verification tools for protocol and stack implementations;
4. Embedded device security & network verification architectures;
5. Leveraging wireless channel and device properties to secure devices and networks;
6. Multifaceted trust and configurable intrinsic security in federated and heterogeneous networks;
7. Novel authentication, authorization, delegation and cryptographic mechanisms; including those that are resilient to quantum-algorithmic attacks; and/or
8. End-to-end secure slice from the end devices through the RAN through the Mobile Core to services.

A2: Network Intelligence/Adaptability: This RV focuses on the design of robust and rapidly adaptable next generation architectures, protocols, and network system management that incorporate intelligence and agility across network system functions, components and services.

Examples of some research topics include, but are not limited to:

1. Multi-agent intelligence with distributed learning, inference & multi-agent federation, and interactive machine learning across the network, including RAN and end-devices;
2. Privacy-preserving machine learning & joint design of distributed learning and networking;
3. Dynamically composable networks and services configured and orchestrated on-demand;
4. Rapidly identify and understand disruptive events through intelligent network forensics; and/or
5. Adaptive edge networks that can maintain critical service support in the face of extreme disruption events.

A3: Autonomy: This RV focuses on the ability of the network to work at a highly functional level without human intervention even during disruptive events.

Examples of some research topics include, but are not limited to:

1. Zero-touch autonomous networks with data-driven communication methods and network system design;
2. Seamless (and secure) orchestration for heterogeneous mobile-edge-cloud systems;

3. Safe and predictable AI for networks – fair, transparent, explainable, robust and resilient to attacks;
4. Rapid, autonomous adaption to reconstitute or reconfigure network functions in response to disruptive events; and/or
5. Real time recovery post attack-detection to meet critical functionality and safety required within the networked system.

A4: Exploratory Resiliency Components: Proposers are free to suggest new modalities that will ensure the resiliency of a NextG network system beyond the three mentioned above. A proposer should make a compelling case for such alternatives in the proposal description.

Group B: ENABLING TECHNOLOGIES

Network systems will continue to be built on enabling components and technologies spanning circuits, devices, antennas, signal-processing algorithms, electromagnetic spectrum, network protocols, computational devices, and storage at the wireless link, edge, core, and the cloud. A rich array of network services is expected to emerge seeking to realize greater synergy across the various component subsystems of the network. These new advances will greatly enhance the performance of the network system in terms of throughput, latency, connection density, application support, and service composability. Proposers must describe how their research will do so by targeting one or more of the following RVs within this group, along with one or more RVs from Group A.

As stated previously, proposals must describe the synergy between the Group A and the chosen Group B RVs, i.e. how the proposed advances in Group B contribute to commensurate advances in Resiliency attributes – this is an essential requirement of the program.

B1: RF and Mixed Signal Circuits, Antennas and Components: To allow resilient computing, communications, and networking operation for NextG network systems, fundamental innovations on the hardware and chip side will be required. Such innovations are expected to support many emerging applications spanning from MHz to THz. Existing and forthcoming applications in the sub-6 GHz frequency range and in the 6 GHz – 10 GHz will require innovations that will allow multiple functionalities by dynamic reconfiguration, as well as a combination of additional modalities such as operations in full duplex, low power, wide-band, and low-noise figure modes, millimeter-wave frequencies and beyond will require innovations to significantly improve efficiency, provide methods to alleviate path loss, signal blockage, and beam tracking with minimal energy consumption. Such innovations are needed for both high-capacity urban uses as well as for cost-efficient broadband services in under-served areas, such as rural communities.

Examples of some research topics include, but are not limited to:

1. Widely tunable RF front ends;
2. Novel RF circuits and electronics with high power-efficiency especially for millimeter-wave and beyond;
3. Circuit and component resiliency for edge- and IoT-devices;
4. Large-scale MIMO systems;
5. Beamforming and multi-functional antennas;
6. Advanced duplexing circuits and technologies; and/or
7. Novel Software Architectures for efficient processing of RF Signals.

B2: Novel spectrum management technologies: NextG network systems will need to support communications over multiple frequency bands of different channel propagation characteristics and/or evolving spectrum-use constraints that might be dictated by technology or policy innovations, innovations in waveform design, source and channel coding, signal processing, advanced antenna technologies, power-efficient spectrum sensing and negotiation protocols are needed to address emerging issues in these new applications and systems.

Examples of some research topics include, but are not limited to:

1. Design of new waveforms, coding, and signal processing methods;
2. At-scale signal processing and control for intelligent surfaces;
3. New multi-band/multi-radio network design, leveraging disparate propagation and licensed/shared/unlicensed spectrum approaches;
4. Advanced spectrum sensing, coordination and adaptation over short time-scales in a sustainable fashion;
5. Edge-to-cloud spectrum management systems for heterogenous networks; and/or
6. Spectrum-aware systems to meet extreme performance requirements (e.g, stringent latency, reliability and localization precision in a manufacturing environment).

B3: Scalable device-to-edge-to-cloud continuum: Emerging edge-computing resources have the promise of offering low-latency and ubiquitous computation to heterogeneous mobile, IoT, and other migratory platforms. At the same time, edge resources provide an intermediary layer between multitude of diverse but constrained end-devices and the larger-scale cloud resources. Understanding how to navigate this device-to-edge-to-cloud continuum is a rich area for research, especially when resiliency, privacy, and multi-tenancy of shared and heterogeneous resources are considered. With the evident shift of a NextG network system towards a software- and service-centric architecture, the network edge plays a vital role in enabling innovations in both network architectures and content-delivery services. This continuum also plays a vital role in ensuring resiliency by enabling scale of performance, orchestration, and automation.

Examples of some research topics include, but are not limited to:

1. Software architectures to support use of energy-efficient and heterogeneous programmable accelerators on end-devices;
2. Software architectures to support edge-to-cloud disaggregation/virtualization;
3. Accelerators and hardware architectures that work in conjunction with software to meet performance and resiliency requirements;
4. Network & service interoperability / distribution / federation across the device-to-edge-to-cloud continuum;
5. Systems that better understand data and computation placement as well as movement between tiers in the device-to-edge-to-cloud continuum to support resilient operations;
6. Privacy and security of data, along with controlled data sharing and data isolation in the device-to-edge-to-cloud continuum;
7. Multi-Dimensional networking systems for ubiquitous and continuous connectivity utilizing diversity of access networks, e.g. terrestrial, airborne, and satellite communications;
8. Dynamic topologies beyond the cellular paradigm of backhaul-and-access to enhance capacity, coverage, and reliability;
9. Software-defined end-to-end architectures for dynamic service-composition beyond traditional network design assumptions; and/or
10. Adaptable and dynamically programmable network systems that can use in-band network telemetry and re-program themselves to achieve desired resiliency.

B4: Merging digital/physical/virtual worlds: NextG network systems are expected to enable advanced applications at-scale, including Augmented/Virtual/eXtended Reality (AR/VR/XR), autonomous driving, massive interactive real-time applications, advanced industrial/manufacturing and scientific user applications, and tele-health. There is a need to develop new integrative technology that is capable of supporting seamless deployment of such applications and meeting their stringent/unique demands. This will include supporting immersive interactions needed to take human augmentation to the next level, as well as developing ubiquitous, low power sensing to sustain real-time operations for long durations. While these technologies are advancing, the

volume of data required, and the latency demands both on processing and on content delivery are still research challenges. Proposals targeting this particular RV must address the challenges faced in the network system context for such applications, and not the development of these applications in isolation.

Examples of some research topics include, but are not limited to:

1. Characterizing the benefits of advanced communications and sensing techniques (e.g., multi-modal sensing, joint radar and communications architectures, low latency and high reliability communications);
2. Networks offering AI computation and analytics services in support of advanced applications.
3. Distributed authorization, privacy and provenance mechanisms for multi-agent control systems;
4. Ubiquitous, low power sensing, and AI-assisted network-driven optimization of collaborative controls applications;
5. Understanding temporal and computational aspects of delivering desired quality of experiences for users given limitations of the underlying communication and computation frameworks, including definition of appropriate metrics;
6. Foundational metrics that combine notions of value of information, computational complexity and learning efficiency to drive integrated designs of compute-communication; and/or
7. Local networking that facilitates holistic operation of multiple disaggregated devices, such as display, audio, compute, fabric sensors etc.

II.2. ROLE OF INDUSTRY FUNDING PARTNERS

The companies specifically listed in this solicitation (Apple, Ericsson, Google, IBM, Intel, Microsoft, Nokia, Qualcomm and VMware) have committed to providing annual contributions to NSF for the purpose of funding proposals awarded under this solicitation. The reference to "industry partners" in this section refers specifically to these entities and their role as funding partners in this solicitation. The contributions from these partners have been agreed upon on the basis of a shared belief in the importance of making progress in the research, education, and workforce development goals identified in this program.

Prior to award, these partner companies will not participate in or observe the review of proposals. After completion of the merit review process, NSF may share with representatives of the industry partners the subset of proposals which are under consideration for funding by NSF, along with corresponding unattributed reviews and panel summaries. NSF will take into consideration the input of all industry funding partners prior to making final funding decisions but will retain final authority for making all award decisions.

NSF will administer awards under the Program in accordance with standard NSF policies and procedures. All awards will be subject to standard NSF terms and conditions. Industry partners will not oversee the activities or use of funds by grantees under this Program, but may engage with grantees as outlined below.

Specifically, post-award, partner companies may make available direct contributions of resources including, but not limited to, software (prototypes or products), data sets, and/or other computing infrastructure. No awardee will be required to use any company's offered contributions.

A company may also arrange to fund its own personnel as researchers to directly participate, part-time or full-time, with awardee project personnel. These arrangements will be optional and upon the mutual consent of the companies and respective awardee institutions. No awardee will be required to accept a company researcher.

NSF will share annual project reports with partner companies and agencies after those reports have been reviewed and accepted by the cognizant NSF Program Officer.

The award terms and conditions will state that awardees shall grant to the sponsoring entities (the Federal Government and all the industry partners named in this solicitation) a non-exclusive, worldwide, paid-up, non-transferable, royalty-free license to all intellectual property rights in any inventions or works of authorship resulting from research conducted under the Program. **[Note: the Bayh-Dole Act provides similar rights to the U.S. Government for patents on inventions made under federal funding.] The license to each industry partner will include its subsidiaries and contractors, at its discretion, to the extent that such use is specifically in connection with the industry partner's products and/or services.** Awardees shall grant the license to each industry partner unless the industry partner opts to decline the license. Such license shall not extend to awardees' background intellectual property; however, individual awardees and industry partners may negotiate, voluntarily, in good faith, a mutually acceptable resolution to background intellectual property, if desired, though NSF shall neither enforce nor participate in any such negotiations between awardees and industry partners, nor will any funds provided by NSF to the awardee be contingent upon such negotiations. No rights or licenses are granted by the industry partners. Awardees may delay the publishing of data and software describing inventions to first permit the filing of patent applications. That said, NSF terms and conditions will require that awardees promptly publish all results, data, and software generated in performance of the research.

Proposals to this program may not list or describe any kind of agreed or assumed arrangement to use the contributions described above or any other collaborative arrangement with this solicitations partner companies, beyond what is described in the eligibility section of this solicitation. Proposals that include such arrangements or collaborations with these partners will be returned without review. Exception: Proposers are not restricted from making use of the widely accessible products or services of partner companies.

Proposers to this program should not directly contact industry partners with questions pertaining to their company's participation in this solicitation. All questions should be directed to the program points of contact listed in the solicitation.

II.3. CLOUD COMPUTING RESOURCES

Proposals may request cloud computing resources to use public clouds such as Amazon Web Services (AWS), Google Cloud Platform (GCP), IBM Cloud, and Microsoft Azure. Cloud computing resources described in proposals may be obtained through an external cloud access entity (CloudBank) supported by NSF's Enabling Access to Cloud Computing Resources for CISE Research and Education (Cloud Access) program.

Proposers should describe this request in a Supplementary Document including: (a) which public cloud providers will be used; (b) anticipated annual and total costs for accessing the desired cloud computing resources, based on pricing currently available from the public cloud computing providers; and (c) a technical description of, and justification for, the requested cloud computing resources. The proposal budget should not include the costs for accessing public cloud computing resources via CloudBank. Also, the total cost of the project, including the cloud computing resource request, may not exceed the budget limit described in this solicitation. Proposers may contact CloudBank (see https://www.cloudbank.org/faq) for consultation on estimating the costs for using cloud computing resources.

See Section V.A. Proposal Preparation Instructions, Supplementary Documents, for more information on how to describe the cloud computing resource request as well as the associated budget.

II.4. EVALUATION

Proposers should consider utilizing publicly available wireless- and cloud-related resources to evaluate or demonstrate their innovations. Evaluation of new

technologies through wireless testbeds and collaborations with government labs or industry are examples. These could include NSF-funded platforms such as the NSFFutureCloud projects (Chameleon Lab and CloudLab), FABRIC, and PAWR platforms, as well as NIST testbeds and facilities, NIST-led NextG channel model alliance and data repository.

II.5. Webinar Information

NSF will hold an informational webinar in May 2021. Shortly after publication of this solicitation, the date and registration information, will be posted on the Program Web page.

III. AWARD INFORMATION

Approximately 36-48 awards are anticipated, each up to $1,000,000 total and up to 3 years in duration, subject to the availability of funds and quality of proposals received.

The budget should be commensurate with the scope of the proposed research.

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:

By the submission deadline, any PI, co-PI, or other senior project personnel must hold either:

- a tenured or tenure-track position, or
- a primary, full-time, paid appointment in a research or teaching position

at a U.S.-based campus of an institution eligible to submit to this solicitation (see above), with exceptions granted for family or medical leave, as determined by the submitting institution. Individuals with primary appointments at for-profit non-academic organizations, non-profit non-academic organizations, or at overseas branch campuses of U.S. IHEs are not eligible.

Researchers from foreign academic institutions who contribute essential expertise to the project may participate as senior personnel or collaborators but may not receive NSF support.

Guidelines for the Participation of Partner Companies and Affiliated Individuals in Proposals:

Guidelines for Partner Companies:

A partner company is not permitted to participate in proposals to the program.

*Guidelines for Individuals Affiliated with Partner Companie*s:

Individuals affiliated with a partner company may participate in proposals to the program subject to certain limitations and allowances. These limitations and allowances apply to individuals who are currently employed by, consulting for, or on an active agreement to provide services for the company. Specifically:

- Such individuals may not participate in their capacity with the company.
- Such individuals may participate if they (i) hold a primary appointment at another organization not partnered on the program (e.g., a primary academic appointment at an institution of higher education), as applicable to and defined by that organization, and (ii) do so strictly in their capacity at that other organization.

Proposals that violate the above restrictions may be returned without review.

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 be listed as PI, co-PI, and/or senior personnel on no more than two proposals submitted in response to this solicitation. In the event that an individual exceeds this limit, only the first two proposals received before the deadline will be accepted, and the remainder will be returned without review.

Additional Eligibility Info:

Separately submitted collaborative proposals are not allowed. Support for non-lead collaborating organizations should be requested as subawards. Subawardee institutions are subject to the same eligibility restrictions as those noted above. Separately submitted collaborative proposals will be returned without review.

Each proposal must include a PI and one or more co-PIs forming a team with complementary expertise.

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 FastLane, Research.gov, or Grants.gov.

- 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) 292-8134 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 Research.gov: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal and Award Policies and 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) 292-8134 or by e-mail from nsfpubs@nsf.gov. The Prepare New Proposal setup will prompt you for the program solicitation number.
- 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) 292-8134 or by e-mail from nsfpubs@nsf.gov.

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.

Collaborative Proposals:
Separately submitted collaborative proposals are not allowed. Support for non-lead collaborating organizations should be requested as subawards. *Separately submitted collaborative proposals will be returned without review.*

Cover Sheet:
Title: Proposal titles should begin with "RINGS:" then the title.

Project Summary:
Keywords: Each proposal must include the set of RVs addressed in the proposal as a list of keywords, using the format "RV:", among other keywords that characterize the project. For example, a proposal addressing RVs A1 (Full Stack Security) and B3 (Scalable Device-to-Edge-to-Cloud Continuum) must include the keywords "RV:A1, RV: B3", among other keywords.

Proposers requesting cloud resources through CloudBank.org should include "CloudAccess" (one word without space) as a keyword in the Project Summary page.

Project Description:
The Project Description must contain, as a separate section of less than a page, a section titled "Addressing RINGS Solicitation-Specific Review Criteria". This section should provide a description of how the RINGS solicitation-specific review criteria are addressed in the proposal and include references to other relevant sections in the proposal for additional details.

Supplementary Documents:
Letters of Support/Collaboration: Letters of support are not allowed. Letters of collaboration should follow the format specified in the PAPPG Chapter 2.C.2(j). Proposers must not include letters of collaboration from any of the participating organizations listed in this solicitation. *Any proposal that deviates from these guidelines will be returned without review*.

Collaboration Plans: Each proposal must include a Collaboration Plan of up to two pages as a supplementary document. The length of and degree of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Where appropriate, the Collaboration Plan might include: 1) the specific roles of the project participants in all organizations involved; 2) information on how the project will be managed across all the investigators, organizations, and/or disciplines; 3) identification of the specific coordination mechanisms that will enable cross-investigator, cross-organization, and/or cross-discipline scientific integration (e.g., yearly conferences, graduate student exchange, project meetings at conferences, use of the grid for videoconferences, software repositories); and 4) specific references to the budget line items that support collaboration and coordination mechanisms. *If a proposal does not include a Collaboration Plan of up to two pages, that proposal will be returned without review*.

Cloud Computing Resources (if applicable):

If requesting cloud computing resources, include a description of the request (not to exceed two pages) as a supplementary document that includes the: (1) title of the proposal; (2) name of institution(s), (3) anticipated total cost of computing resources, with yearly breakdown; (4) specific cloud computing providers that will be used; and (5) technical description and justification of the request, along with how the cost was estimated. The NSF Budget should not include any costs for accessing cloud computing resources via CloudBank.

Single Copy Documents (if applicable):
Proposers may wish to include proprietary or privileged information as part of their proposals. Per PAPPG Chapter II.D.1, NSF defines such information as "patentable ideas, trade secrets, privileged or confidential commercial or financial information, disclosure of which may harm the proposer," While providing this information is not required, a proposer to the RINGS program who wishes to include proprietary or privileged information *must* provide any and all such information as a Single-Copy Document in the Proposal Preparation Module in FastLane or Research.gov. That is, this information shall not appear in other parts of the proposal. In keeping with NSF's practice, the Single Copy Document will not be shared with reviewers, OUSD R&E, NIST, or industry partners.

While NSF will make every effort to prevent unauthorized access to such material, the Foundation is not responsible or in any way liable for the release of such material.

Note: Because proprietary or privileged information may only be specified in the Single Copy Document, PIs should not check the "Proprietary or Privileged Information" box on the Cover Sheet; that box applies only to such content appearing in the body of a proposal.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Budget Preparation Instructions:

Each proposal budget must include funding for a PI or co-PI and up to one other project participant to travel to and attend annual two-day PI meetings in the Washington, DC, area during the award period.

The total budget of the project, including any cloud computing resource request from CloudBank.org, may not exceed the budget limits described in this solicitation. The total cost of the cloud computing resources requested from Cloudbank.org should not be included in the NSF budget, and should be specified only in the associated supplementary document as noted above.

Example: Given the solicitation budget limit of $1,000,000, if a PI wishes to request $50,000 in cloud computing resources through CloudBank, then the proposal budget should not exceed $950,000. The $50,000 for cloud computing resources should be specified in the Supplementary Document. If a proposal involves PIs from multiple organizations, then a single Supplementary Document should capture the various cloud computing resource requests across the organizations.

C. Due Dates

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

    July 29, 2021

D. FastLane/Research.gov/Grants.gov Requirements

For Proposals Submitted Via FastLane or Research.gov:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: https://www.fastlane.nsf.gov/a1/newstan.htm. To prepare and submit a proposal via Research.gov, see detailed technical instructions available at: https://www.research.gov/research-portal/appmanager/base/desktop?_nfpb=true&_pageLabel=research_node_display&_nodePath=/researchGov/Service/Desktop/ProposalPreparationandSubmission.html. For FastLane or Research.gov user support, call the FastLane and Research.gov Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov or rgov@nsf.gov. The FastLane and Research.gov Help Desk answers general technical questions related to the use of the FastLane and Research.gov systems. 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: https://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 or Research.gov may use Research.gov 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

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) 292-8134 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:

ACKNOWLEDGEMENT OF SUPPORT:
Awardees will be required to include appropriate acknowledgment of NSF, OUSD R&E, NIST, and industry partners support in reports and/or publications on work performed under an award. An example of such an acknowledgement would be: "This material is based upon work supported by the National Science Foundation under grant no. (NSF grant number) and is supported in part by funds from federal agency and industry partners as specified in the Resilient & Intelligent NextG Systems (RINGS) program."

PI MEETINGS:
The program plans to host PI meetings in the Washington, DC, area every year with participation from all active projects. This meeting will be a community-wide event with representatives from federal agencies, academia, industry, and international institutions. The first PI meeting is expected to be held in Fall 2022. At least one PI or co-PI and up to one other project participant must attend each PI meeting. Participation of at least two representatives from a multi-institution project is required, but attendance of a representative from every institution participating in that project is not required.

PARTNER ENGAGEMENT:
Once the Program awards have been issued, each of the partner organizations (other than NSF) may engage with the awardees in the following ways:

- Representatives may attend the annual PI meetings;
- Organization may provide software (prototypes or products), data sets, other computing infrastructure, and/or other such support to all awardees; although awardees will not be required to use the participating organization's offered contributions;
- Organization may offer to provide resources and opportunities (e.g., seminars, internships) to all awardees, although awardees will not be required to use participating organization's offered contributions; and/or
- Organization may separately offer to fund its own personnel as researchers to directly participate, part-time or full-time, with the funded awardees, pursuant to terms and conditions agreed upon between the participating organization and the funded awardee. Such a researcher is an organization representative actively participating with the funded research team. Depending on organization's capacity to provide such a researcher, it is possible that not all awardees interested in hosting a researcher will have access to them. Optional deployment of one or more researchers will require mutual consent by the participating organization and the awardee for each award made under this program. In no case will any awardee be required to accept a partner's researcher, nor will a partner's researcher be required to engage with an awardee.

Additionally, proposers should plan that NSF or a NSF-funded coordination entity will facilitate engagement between NSF, partners, and awardees, including on research dissemination, workshops, collaborative engagements, and other activities that support nurturing and growing the RINGS community. Awardees must engage with NSF and/or the coordination entity on these activities throughout the duration of the grant.

INTELLECTUAL PROPERTY:
Awardees shall grant to the industry partners named in this solicitation a non-exclusive, worldwide, paid-up, non-transferable, royalty-free license to all intellectual property rights in any inventions or works of authorship resulting from research conducted under the Program. [Note: the Bayh-Dole Act provides similar rights to the U.S. Government for patents on inventions made under federal funding.] The license to each industry partner will include its subsidiaries and contractors, at its discretion, to the extent that such use is specifically in connection with the industry partner's products and/or services. Awardees shall grant the license to each industry partner unless the industry partner opts to decline the license. Such license shall not extend to awardees' background intellectual property; however, individual awardees and industry partners may negotiate, voluntarily, in good faith, a mutually acceptable resolution to background intellectual property, if desired, though NSF shall neither enforce nor participate in any such negotiations between awardees and industry partners, nor will any funds provided by NSF to the awardee be contingent upon such negotiations. No rights or licenses are granted by the industry partners. Awardees may delay the publishing of data and software describing inventions to first permit the filing of patent applications. That said, NSF terms and conditions will require that awardees promptly publish all results, data, and software generated in performance of the research.

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.

Each partner organization will receive copies of reports from the awardees after approval by the cognizant NSF program officer. The partner organization may opt to decline to receive these reports, particularly if they contain proprietary or privileged information. If reviewing project reports gives the partners access to information not generally available to the public, then they agree not use that information for their personal benefit nor make it available for the personal benefit of any other individual and/or organization. Further, the partners agree not to disclose any non-public information to any institution of higher education or organization outside of their organization.

It is expected that research outcomes will be disseminated consistent with the Data Management Plan Guidance for CISE proposals and awards: https://www.nsf.gov/cise/cise_dmp.jsp.

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:

- Alexander Sprintson, CISE/CNS, telephone: (703) 292-8950, email: asprints@nsf.gov
- Murat Torlak, CISE/CNS, telephone: (703) 292-7748, email: mtorlak@nsf.gov
- Mohammod Ali, ENG/ECCS, telephone: (703) 292-4632, email: moali@nsf.gov
- Erik Brunvand, CISE/CNS, telephone: (703) 292-8950, email: ebrunvan@nsf.gov
- Phillip A. Regalia, CISE/CCF, telephone: (703) 292-2981, email: pregalia@nsf.gov
- Zhengdao Wang, ENG/ECCS, telephone: (703) 292-7823, email: zwang@nsf.gov

For questions related to the use of FastLane or Research.gov, contact:

- FastLane and Research.gov Help Desk: 1-800-673-6188
- FastLane Help Desk e-mail: fastlane@nsf.gov
- Research.gov Help Desk e-mail: rgov@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 https://www.grants.gov.

ABOUT THE NATIONAL SCIENCE FOUNDATION

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

NSF funds research and education in most fields of science and engineering. It does this through grants and cooperative agreements to more than 2,000

colleges, universities, K-12 school systems, businesses, informal science organizations and other research organizations throughout the US. The Foundation accounts for about one-fourth of Federal support to academic institutions for basic research.

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

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

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

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

> The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.
>
> To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at https://www.nsf.gov
>
> - **Location:**   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) 292-8134
>
> - **To Locate NSF Employees:**   (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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