NSF 24-545: Ideas Lab: Breaking the Low Latency Barrier for Verticals in Next-G Wireless Networks

Program Solicitation

Document Information

Document History

- **Posted:** February 20, 2024

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National Science Foundation
Directorate for Technology, Innovation and Partnerships
Innovation and Technology Ecosystems

Preliminary Proposal Due Date(s) ***(required)*** (due by 5 p.m. submitter's local time):

April 18, 2024

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

September 30, 2024

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Important Information And Revision Notes

Any proposal submitted in response to this solicitation should be submitted in accordance with the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) that is in effect for the relevant due date to which the proposal is being submitted. The NSF PAPPG is regularly revised and it is the responsibility of the proposer to ensure that the proposal meets the requirements specified in this solicitation and the applicable version of the PAPPG. Submitting a proposal prior to a specified deadline does not negate this requirement.

Summary Of Program Requirements

General Information

Program Title:

Ideas Lab: Breaking the Low Latency Barrier for Verticals in Next-G Wireless Networks (Breaking Low)

Synopsis of Program:

The U.S. National Science Foundation's Directorate for Technology, Innovation and Partnerships (TIP) is charged with accelerating use-inspired and translational research and development (R&D) to advance U.S. competitiveness in key technology focus areas. The *Breaking the Low Latency Barrier for Verticals in Next-G Wireless Networks (Breaking Low)* initiative will accelerate and enable new technologies and contribute to the growth of the U.S. economy in advanced wireless communications.

TIP is seeking to identify and address critical architectural, technical and technological issues that must be resolved in fifth-generation (5G) and next generation (Next-G) wireless networks to provide the necessary low-latency performance that is required for the success of key emerging vertical industries. Most current public cellular deployments are unable to support end-to-end (E2E) latencies that are consistently below 10 milliseconds (ms) and Wireless Local Area Network (WLAN) latencies below 10 ms are possible only under certain favorable conditions (low network load, high bandwidth) even with Wi Fi 6 (IEEE 802.11ax). The Next-G mobile network use cases are expected to demand even more stringent latency and reliability requirements as network designers seek to raise the bar with better performance. A closer examination of the current state of the art reveals that there are critical bottlenecks at various points in the end-to-end network path from the application to the cloud resulting from the existing design, architectural, protocol, processing, optimization and implementation choices across both control and user planes, as well as the lack of low-latency vertical applications-driven technology development.

This solicitation describes an Ideas Lab focused on low-latency wireless networks and vertical applications that rely on them to:

a. identify cost-effective novel approaches that have the potential to break the hurdles that exist in today's networks, including 5G/Next-G cellular, WLAN, access and cloud components, to meet the end-to-end low-latency and high-reliability targets required to enable specific emerging vertical use cases;

b. formulate and execute a coherent research and development (R&D) plan that will lead to the technological advances necessary to engineer Next-G advanced wireless networks that meet the desired low-latency and high-reliability demands of identified vertical applications; and

c. prototype and demonstrate the developed technology solutions in at-scale testbeds for specific vertical use cases under a wide range of relevant network conditions.

The Ideas Lab Workshop is an interactive gathering of experts and stakeholders interested in collaboratively developing potential solution approaches to a specific problem or a grand challenge. It is expected to be a three-day-long intensive and focused meeting. The participants are drawn from diverse backgrounds and a broad range of expertise areas relevant to the posed problem of interest. The goal is to facilitate a brainstorming effort among a team of experts who may not otherwise come together to solve the specific posed problem though all their experiences, expertise and the needs are very much relevant to the problem. Hence, ideally, the participants are expected not to have had significant prior research or technology development interactions among them.

This Ideas Lab workshop, in particular, aims to bring together, and facilitate a dialogue among a group of innovators with diverse perspectives, experiences and expertise to stimulate creative thinking and collaborative spirit to develop and validate innovative low latency communications technologies that will help meet, and possibly exceed, Next-G mobile wireless network specifications to spur a great number of emerging applications within multiple vertical industries that will transform the way we live and interact with each other. It is expected that the participation of key stakeholders and experts from low-latency vertical application use cases in the Ideas Lab workshop, in addition to the networking/computing researchers and technical experts, may contribute to achieving the goals of this Ideas Lab program.

The solicitation expects robust partnerships between both academia and industry in the wireless telecom, vertical application and cloud computing sectors to co-design solutions to meet the requirements of specific low-latency verticals including rapid prototyping, testing, validation and at-scale pilot demonstrations. It is the belief of NSF that adoption of the resultant solutions will be hastened through such partnerships and thus NSF encourages applications from both academia and industry (both wireless as well as application verticals).

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.

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

- 47.084 --- NSF Technology, Innovation and Partnerships

Award Information

Anticipated Type of Award: Cooperative Agreement

Estimated Number of Awards: 4

Up to 4 awards are anticipated depending upon availability of funds and the type, scale, quality, transformative-potential, and diversity of project ideas developed at the Ideas Lab. Awards will be funded up to $3,700,000 per year for up to 2 years commensurate with the complexity of the proposed research and development plan and the final maturity level and translational potential of the resulting technology.

Anticipated Funding Amount: $12,000,000

The total funding available for this Ideas Lab is $12,000,000 over 2 years for up to 4 selected awards. Estimated program budget, number of awards and average award size/duration are subject to the 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.
- Non-profit, non-academic organizations: Independent museums, observatories, research laboratories, professional societies and similar organizations located in the U.S. that are directly associated with educational or research activities.
- For-profit organizations: U.S.-based commercial organizations, including small businesses, with strong capabilities in scientific or engineering research or education and a passion for innovation.
- State and Local Governments: State educational offices or organizations and local school districts.
- Tribal Nations: An American Indian or Alaska Native tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges as a federally recognized tribe pursuant to the Federally Recognized Indian Tribe List Act of 1994, 25 U.S.C. §§ 5130-5131.
- Other Federal Agencies and Federally Funded Research and Development Centers (FFRDCs): Contact the appropriate program before preparing a proposal for submission.

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 serve as PI or co-PI on only one Ideas Lab proposal in this competition but may serve as other Senior/Key Personnel or Other Personnel on any number of Ideas Lab proposals in this competition.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not required
- **Preliminary Proposals:** Submission of Preliminary Proposals is required. Please see the full text of this solicitation for further information.
- **Full Proposals:**
    - 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

- **Preliminary Proposal Due Date(s) *(required)*** (due by 5 p.m. submitter's local time):

  April 18, 2024

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

  September 30, 2024

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:

Standard NSF award conditions apply.

Reporting Requirements:

Standard NSF reporting requirements apply.

I. Introduction

The U.S. National Science Foundation's Directorate for Technology, Innovation and Partnerships (TIP) is charged with accelerating use-inspired and translational research and development (R&D) to advance U.S. competitiveness in key

technology focus areas. The *Breaking the Low Latency Barrier for Verticals in Next-G Wireless Networks (Breaking Low)* Ideas Lab investment will accelerate and enable new technologies and contribute to the growth of the U.S. economy in advanced wireless communications.

Reduced end-to-end (E2E) latency has enabled many networked applications that are now considered essential. For example, video conferencing across wide area networks was not popular until average E2E latencies were brought down to be consistently under 300 milliseconds (ms) in the early 2000s, and now it is a mainstay of productivity – connecting businesses and people in meaningful ways. In recent years, technologies such as fifth generation (5G) cellular, IEEE 802.11ax for Wi Fi, edge and cloud computing have helped reduce E2E latencies by an order of magnitude, enabling new applications such as real-time music jamming, wide-area network gaming and virtual reality. These applications are, however, in the nascent stages of their adoption by the populace, with one of the barriers for wider adoption being the lack of consistent latency performance.

Ultra-low latencies are also critical for some of the emerging vertical applications including, for example, extended reality (XR) applications such as holographic/immersive communications, intelligent/autonomous transportation systems, emergency services, telemedicine/remote healthcare, real-time haptics including wearable medical devices and remote surgery, tactile internet, electrical power transmission and distribution systems, the industrial Internet of Things (IIoT), and cyber-physical/distributed automation (e.g. factory automation). For example, latencies on the order of a millisecond or less are seen as a requirement in industrial automation applications involving precision motion and machine control. Some of these potential applications also demand that ultra-low latencies are guaranteed with high reliability.

The vertical industries that were to be enabled by the 5G wireless and other advanced communication networks, particularly many requiring low-latency communications, are yet to take off at a wide scale. This can be attributed, at least in part, to the fact that deployed networks still do not offer latencies on the order of a few milliseconds. Indeed, measurement data from 5G Mobile Network Operators (MNOs) shows that user-experienced latencies are on the order of a few tens of milliseconds. The expectation is that sub-millisecond latencies may only be achieved in dedicated (private) 5G networks at the cost of additional radio resources. Similarly, below 10 ms latencies in Wi Fi 6 Wireless Local Area Networks (WLANs) are only possible under favorable conditions such as low network load and higher bandwidths. In addition, uplink latencies can sometimes be more than double the corresponding downlink latencies making E2E latency guarantees required in both directions. To enable low-latency vertical applications, the Control Plane (CP) latency may also need to be taken into account along with service availability/reliability. Though MNOs claim that 5G Standalone (5G SA) mode networks can meet the low-latency and reliability specifications, this is yet to be proven in the field.

There exists a significant need to understand and verify the exact latency guarantees needed for specific vertical applications followed by technology demonstration of how such requirements (e.g., E2E latencies of a few milliseconds with high reliability) can be achieved in 5G and next generation (Next-G) networks without compromising the spectral efficiencies that impact the profitability of deployments.

This solicitation describes an Ideas Lab focused on reliable low-latency communications and vertical applications that rely on them to:

a. identify novel cost-effective approaches that have the potential to break the existing critical bottlenecks in today's networks, including 5G/Next-G cellular, WLAN, access and cloud components, in meeting the desired E2E latency and associated jitter targets demanded by specific emerging vertical industries while maintaining adequate spectral efficiency;

b. formulate and execute a coherent research & development (R&D) plan that will lead to technological advances necessary to engineer the next-generation advanced wireless networks that meet the desired low latency and reliability demands of specific vertical applications at a competitive price point; and

c. prototype and validate the developed technology solutions in specific vertical use cases under a wide-range of practical network conditions in at-scale testbed and pilot demonstrations.

The vision of this Ideas Lab is to support R&D that will dramatically reduce the E2E latencies cost-effectively to spur a great number of emerging vertical industries that will transform the way we live and interact with each other. While the vision of this Ideas Lab is to develop and validate technological solutions that achieve the above E2E latencies at service

reliabilities demanded by specific low-latency application verticals using wide-area 5G networks and WLANs for last-mile access, novel solutions that can outperform such thresholds are encouraged.

II. Program Description

This Ideas Lab (see PAPPG Chapter II.F.6) plans to bring together researchers, innovators, technology developers and vertical industry stakeholders from diverse scientific, engineering, and technological backgrounds who may not otherwise have the opportunity, the need or the incentive to collaborate towards solving the broader research and technological challenges (a) – (c) posed in Section I above. The innovations sought are across the entire network, compute and application stack, considering the availability and use of computational resources in the cloud and/or edge, including but not limited to artificial intelligence (AI) techniques. The brainstorming facilitated by the Ideas Lab setting will stimulate fresh out-of-the-box thinking and innovative approaches that will provide a fertile ground for new and bold ideas on the design of architecture, components and protocols of next-generation advanced wireless networks and edge-cloud systems.

The goal is for researchers, engineers, technology entrepreneurs and stakeholders (from wireless telecom, vertical application and cloud computing sectors) who are experts in their respective domains to come together and form collaborative teams during the Ideas Lab workshop. The teams will formulate innovative and transformative ideas that will eventually be submitted as full proposals to develop and demonstrate low-latency communications technologies that can potentially be standardized and commercialized.

1. Problems to be solved and objectives

Since an application relies on connectivity seamlessly switching between any available network interface (such as Wi Fi, Ethernet, Bluetooth, satellite and/or cellular interfaces), from an application point of view, the focus has to be on the E2E, or even round-trip-time (RTT), latency along with reliability requirements of specific vertical use cases. While individual standards such as the IMT-2020 Standard for 5G networks, devices and services, issued by the International Telecommunication Union Radiocommunication Sector (ITU-R), specify link-level latency requirements, the perceived quality of the services experienced by the users is ultimately driven by the E2E latency performance.

Typical network latency analyses show that the air interface is a primary contributor to E2E latency. Among the common air interfaces used today, in 5G networks, such latency is primarily dictated by the protocols and Orthogonal Frequency Division Multiplexing (OFDM) sub-carrier spacing (SCS) whereas architectural and optimization aspects greatly influence the Radio Access Network (RAN) and Core Network (CN) latencies. Similarly, the latency performance of Wi Fi 6 is seen as underwhelming and inadequate for real-time applications that demand latencies of a few milliseconds, leading to the on-going work on Wi Fi 7 (IEEE 802.11be) aimed, in part, at improving the worst-case latency and jitter. There are other contributors on the access network design and cloud processing components as well. It is conceivable that a combination of novel network design, architectural, access and protocol choices along with processing and optimization algorithms may help significantly reduce the E2E latency and jitter and improve reliability, in a manner that does not compromise the spectral efficiency of the network adversely and lead to overall reduction in service quality. This Ideas Lab is expected to bring together researchers, developers, practitioners and stakeholders of wireless technologies and low-latency vertical industries to identify the limitations in current designs and develop and demonstrate potential solutions that will achieve E2E latencies required for specific emerging ultra-low-latency vertical applications of 5G/Next-G cellular and WLANs at competitive cost.

There is a realization that Next-G communication networks can further build on fundamental design ideas and shifts that started with 5G, including, for example, the separation of control and user planes, OFDM numerologies, virtualized and cloud-native core, mini-slots and grant-free access, to make the future networks simpler and more flexible. Novel designs incorporating emerging concepts such as RAN - CN convergence, Mobile Edge Computing (MEC) and integrated access and side-link communications may also help reduce latencies in Next-G networks. Additional innovations in cloud processing and edge computing can eliminate application-level performance bottlenecks. Overcoming current gridlock in delivering millisecond scale E2E latencies with very high service reliability at competitive cost may still require novel, disruptive and joint design approaches that consider the E2E latency from User Equipment (UE) to the CN.

An important aspect of emerging wireless networks is their drift towards open-source hardware and software implementations. For example, open RAN, open Core and open-source software-defined radios (SDR) have already gained significant traction among the research community and the industry. It is important that potential technological advances targeted towards ultra-low-latency communications are compatible with the emerging open-source ecosystems.

2. Research and Technology Tracks

This Ideas Lab is intended to identify critical technical, architectural and technological barriers hindering low-latency targets of Next-G networks, articulate innovative breakthrough R&D programs that will significantly advance the state of the art so that ultra-low-latency performance critical for emerging vertical industries can be achieved and validate the developed technologies in specific vertical application use cases under a range of network conditions in at-scale testbed and pilot demonstrations. Through this Ideas Lab solicitation, NSF challenges the academic research community, industry (representing wireless telecom, vertical applications and cloud/edge computing), and entrepreneurs to come together to collaboratively develop and demonstrate the technology to achieve global leadership in low-latency communications and verticals.

Possible areas of interest for investigation include, but not limited to, the following broad topics:

- Low-latency requirements, bottlenecks and technology solutions for networks utilizing wide-area 5G/Next-G cellular and WLANs to enable specific emerging vertical use cases;
- Pilot low-latency vertical applications and at-scale testbed demonstrations of technology;
- Next-G RAN-Core convergence, side-link and MEC designs for low-latency communications;
- Technologies and services enabling the latency-sensitive distribution and coordination of application-level software functionality, with emphasis on reusable mechanisms to manage, reduce and/or hide latency in order to meet application-specific requirements;
- Ultra-low-latency communications technologies and open-source implementations; and
- Potential technology (both low-latency communications and low-latency verticals) translation and standardization opportunities/efforts

The above topics are intended only as potentially useful starting points for deliberations.

It is expected that the technical and technological breakthroughs resulting from this Ideas Lab will dramatically reduce the E2E latency to meet the latency and reliability requirements demanded by specifically identified low-latency vertical applications while maintaining adequate spectral efficiency and at competitive cost. The proposed approaches should bring high-impact solutions and capabilities to address limitations in current network designs. They may be high-risk, but are expected to be based on sound science and engineering principles and to have the potential to significantly advance the state of the art and help propel forward new low-latency vertical industries.

Following the Ideas Lab workshop (described later in this section), full proposals will be invited focusing on identifying critical technical, architectural and technological barriers hindering low- latency performance targets needed for specific vertical industries from state-of-the-art wide area 5G/Next-G cellular and/or WLAN networks and novel approaches that have the potential to overcome the identified issues as well as on executing a coherent R&D plan that will lead to technological advances necessary to engineer the next-generation mobile wireless networks that meet the desired low latency and cost demands of specific low-latency vertical use cases that have the potential to be breakthrough applications. Proposals are expected to identify specific emerging low-latency communications vertical use cases, the low latency and service reliability requirements of them and develop pilot projects to prototype, test and validate the developed novel technologies in at-scale testbed demonstrations. Proposers are encouraged to leverage existing wireless testbeds, such as the NSF Platforms for Advanced Wireless Research (PAWR)[1] (whenever possible), and to partner with telecom operators, low-latency mobile wireless vertical market stakeholders and edge-cloud service providers to validate developed technological solutions under a wide range of use cases, scale and infrastructure.

Possible deliverables from the funded projects may include prototypes, tests and validations, and at-scale testbed and pilot demonstrations of developed low-latency communications technologies for currently known and/or novel vertical

applications. It is expected that project teams will closely collaborate and coordinate activities to iterate and refine the final technologies and deliverables to ensure the success of the overall program.

The broader goal of this Ideas Lab solicitation is to call for R&D innovations leading to potential technology translation and standardization. Full proposals are encouraged to include a roadmap (with a timeline) with sufficient details on plans for such follow-up activities (both in mobile wireless networking and verticals). NSF may consider supporting follow-up efforts of promising projects through supplemental and/or other funding opportunities, subject to the availability of funds.

3. Expertise Needed from Different Areas

Successful full proposal teams are expected to include experts from wireless telecom, specific low-latency vertical application use cases and cloud service providers. They are expected to combine a broad base of technical expertise and technology development, prototyping, validation and translation experience drawn from both academia and industry.

To that end, NSF encourages submission of preliminary proposals from both academia and industry (from wireless cellular and WLAN networks, low-latency vertical applications, cloud/distributed computing and edge-device platforms), including researchers, R&D leads, stakeholders from low-latency vertical industries, technology developers and tech entrepreneurs so that during the Ideas Lab workshop participants have a good chance to collaboratively develop comprehensive solutions that can be realized in practice.

Note: Prospective PIs are strongly encouraged to consult with the Cognizant Program Officers on the relevant R&D area(s) and technology development aspects prior to submitting a preliminary proposal.

4. The Ideas Lab

The Ideas Lab is an interactive workshop of experts and stakeholders interested in collaboratively developing potential solution approaches to a specific problem or a grand challenge. It is expected to be a 3-day long intensive and focused meeting. The participants are drawn from diverse backgrounds and a broad range of expertise areas relevant to the posed problem of interest. The goal is to facilitate a brainstorming effort among a team of experts who may not otherwise come together to solve the specific posed problem though all their experiences, expertise and the needs are very much relevant to the problem. Hence, ideally, the participants are expected not to have had significant prior research or technology development interactions among them.

This Ideas Lab workshop, in particular, aims to bring together, and facilitate a dialogue among, a group of innovators with diverse perspectives, experiences and expertise to stimulate creative thinking and collaborative spirit to develop and validate innovative low-latency communications technologies that will help meet, and possibly exceed, Next-G mobile wireless network specifications to spur a great number of emerging applications within multiple vertical industries that will transform the way we live and interact with each other. It is expected that the participation of key stakeholders and experts from low-latency vertical application use cases in the Ideas Lab workshop, in addition to the networking/computing researchers and technical experts, may contribute to achieving the goals of this Ideas Lab program.

Collaboration and free exchange of innovative ideas is an integral aspect of the concept of the Ideas Lab. Participants of the workshop are expected to engage constructively and professionally with one another, the facilitators, Workshop Director(s) and the mentors to develop collaborative research and research & development proposals.

4.1 How will the Ideas Lab Work?

The Ideas Lab is an intensive, interactive, and free-thinking environment, where a diverse group of participants from a range of disciplines and backgrounds gets together, away from their daily routines, to immerse themselves in collaborative thinking in order to construct innovative solutions and approaches for identifying and tackling challenging problems. The in-person Ideas Lab workshop will run over three days. The in-person workshop will be proceeded and followed by a set of virtual meetings to allow the participants to get to know each other and teams to further exchange and develop their ideas.

The participants of the Ideas Lab workshop will work collaboratively to identify E2E low-latency requirements of specific vertical use cases and critical technology gaps to cost effectively realize those low-latency performance targets in wide-area 5G/Next-G cellular and WLAN deployments. They will define the scope of the R&D, vertical use case pilot projects and at-scale testbed demonstration challenges relating to the design, development, and deployment of 5G/Next-G networks that may overcome the identified shortcomings of current offerings. As the Ideas Lab progresses, participants will dynamically develop, iterate and refine novel ideas about how the identified challenges may be addressed, and then use these ideas and approaches to develop comprehensive solutions, which would contain genuinely innovative investigations that may lead to potentially disruptive technological advances breaking new ground in ultra-low-latency communications and the vertical markets enabled by extremely reliable low-latency wireless networks. Proposals taking high risk while being grounded in sound science and fundamental engineering principles and with the potential for high impact are especially encouraged.

The nature of the Ideas Lab requires a high degree of trust, mutual respect and collaborative spirit among participants in order to make the previously impossible breakthroughs in scientific thinking and engineering designs. This trust extends to allowing the free and frank exchange of scientific, engineering and technological ideas, some being in the very early stages of development. The aim of the Ideas Lab is not to discuss ideas that are already well-developed but not yet published. Rather, the goal is to bring individuals with different expertise, experiences and perspectives together to interact and engage to learn from one another and develop a comprehensive research and technological roadmap to achieve ultra-low-latency performance demanded from Next-G mobile wireless networks. It is expected that the sharing of these ideas will be encouraged within the Ideas Lab, but their confidentiality will be respected outside the Ideas Lab.

The Ideas Lab will be led by a Workshop Director (or Directors) whose role will be to assist in defining the topics and help facilitate discussions at the event. The Workshop Director(s) will be joined by a small number of mentors and a team of professional facilitators. The mentors will be selected by NSF based on their intellectual standing, their impartiality and objectivity, and their broad understanding of, and enthusiasm for, the subject area. The Workshop Director(s) and mentors will take full part in the Ideas Lab but will not be eligible to receive research funding under this collaborative activity. They will, therefore, act as impartial peer reviewers in the process, providing a function analogous to that of an NSF review panel.

The process can be broken down into several stages:

- Defining the scope of the challenges;
- Evolving common languages and terminologies amongst people from academia, industry, vertical markets and technology translation as well as with diverse expertise domains (e.g., hardware, software, vertical applications);
- Sharing perspectives and understanding of the technical challenges, as well as the diverse expertise brought by the participants to the Ideas Lab;
- Taking part in break-out sessions focused on the challenges, using creative thinking and collaborative problem-solving techniques;
- Capturing the outputs in the form of highly innovative potential solutions;
- Integrating solution approaches to develop comprehensive technology development and validation projects; and
- Using "real-time" peer review to revise and refine comprehensive technology development and validation projects at the Ideas Lab.

The Ideas Lab will be an intensive event with opportunities for networking and other activities as a break from the intensive technical discussions.

5. Award Selection Process

This Ideas Lab activity will consist of the following three stages:

1) *Preliminary Proposal:* Any individual (not an organization or group of collaborators) interested in participating in this Ideas Lab should respond to this solicitation by submitting a preliminary proposal (see Section V). The preliminary proposals will be reviewed by NSF and a subset of respondents will be invited to participate in the Ideas Lab Workshop.

Participants will be selected on the basis of the interests, expertise, experience and other relevant characteristics described in the submitted preliminary proposals. Submission of a preliminary proposal will be considered an indication of availability to attend and participate in the full course of the Ideas Lab Workshop described below.

2) *Ideas Lab Workshop:* The Ideas Lab workshop will be held to allow the invited experts to exchange ideas and form collaborative teams formulating comprehensive solutions to the problems/challenges posed in this solicitation. At the end of the workshop, the self-assembled collaborative teams will pitch their proposed R&D and technology development solution approaches for a full proposal to NSF.

3) *Full Proposal:* Selected collaborative teams from the Ideas Lab will be invited to submit full proposals to NSF by the full proposal deadline. Additional expertise needed for the success of the proposed activities can be added after the Ideas Lab Workshop. These full proposals must reflect the outline developed and pitched to NSF at the Ideas Lab workshop. The full proposals will undergo merit review, and a subset of the full proposals will be selected for awards.

6. Who Should Apply to Participate?

Having the right mix of participants is critically important to achieving the goals of this Ideas Lab. Defining requirements and developing technological solutions will require teams to be made of technical experts (in wireless cellular and WLAN networks, emerging low-latency vertical applications, cloud/distributed computing and edge-device platforms) and entrepreneurs, developers, practitioners, testbed operators, and other stakeholders of low-latency communications. Applications are encouraged from all of these communities. In particular, the experts representing all relevant technical domains to the posed problem, working across all layers of the network stack, and low-latency vertical application developers are highly encouraged to apply.

The Ideas Lab approach is about bringing people together who may not normally interact or collaborate to solve the posed technological challenge. Hence, individuals who are experts in their own research areas that contribute to latency aspects of 5G/Next-G wireless networks but may not have a well-developed comprehensive solution to the posed technical challenges as well as low-latency vertical industry stakeholders who are interested in evaluating/demonstrating their products/services are actively encouraged to apply.

7. Location and Date

This Ideas Lab workshop is planned to take place in July 2024, with the in-person event scheduled for July 22-24, 2024. The environment will encourage free and open-minded thinking, vital for the purposes of this event. Additional information about the venue and meeting logistics will be provided to the selected participants. Travel to the Ideas Lab workshop, accommodation, refreshments, breakfast, lunch, and dinner costs will be covered by NSF. However, all incidental costs incurred while at the event will be borne by the participant.

[1] https://advancedwireless.org/

III. Award Information

Up to 4 awards are anticipated depending upon availability of funds and the type, scale, quality, transformative-potential, and diversity of project ideas developed at the Ideas Lab. Awards will be funded up to $3,700,000 per year for up to 2 years commensurate with the complexity of the proposed research and development plan and the final maturity level and translational potential of the resulting technology.

The total funding available for this Ideas Lab is $12,000,000 over 2 years for up to 4 selected awards.

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.
- Non-profit, non-academic organizations: Independent museums, observatories, research laboratories, professional societies and similar organizations located in the U.S. that are directly associated with educational or research activities.
- For-profit organizations: U.S.-based commercial organizations, including small businesses, with strong capabilities in scientific or engineering research or education and a passion for innovation.
- State and Local Governments: State educational offices or organizations and local school districts.
- Tribal Nations: An American Indian or Alaska Native tribe, band, nation, pueblo, village, or community that the Secretary of the Interior acknowledges as a federally recognized tribe pursuant to the Federally Recognized Indian Tribe List Act of 1994, 25 U.S.C. §§ 5130-5131.
- Other Federal Agencies and Federally Funded Research and Development Centers (FFRDCs): Contact the appropriate program before preparing a proposal for submission.

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 serve as PI or co-PI on only one Ideas Lab proposal in this competition but may serve as other Senior/Key Personnel or Other Personnel on any number of Ideas Lab proposals in this competition.

V. Proposal Preparation And Submission Instructions

A. Proposal Preparation Instructions

Preliminary Proposals *(required)*: Preliminary proposals are required and must be submitted via Research.gov, even if full proposals will be submitted via Grants.gov.

Please note, the preliminary proposal must come from one individual and cannot include co-PIs or collaborators. Participants for the Ideas Lab will be selected on the basis of information submitted in the preliminary proposal.

Preliminary Proposal Set-Up: Select "Prepare New Preliminary Proposal" in Research.gov. Search for and select this solicitation title in Step 1 of the Preliminary Proposal wizard. The information in Step 2 is pre-populated by the system.

Title: The title format is "Ideas Lab: Breaking Low Preliminary Proposal:" followed by a descriptive title. Please note that Research.gov will automatically prepend the title with "Ideas Lab:".

As described in the PAPPG Chapter II.F.6, the **Project Description** section of the preliminary proposal is limited to two pages and should conform to the following guidelines:

Page One:

Q1. Please provide a brief summary of your professional background and career highlights, including any relevant technical expertise, R&D experience, technology development, translation, deployment and commercialization in or related to low-latency advanced wireless telecommunications/cloud networks, or low-latency vertical applications of 5G/Next-G or WLAN networks.

Please note that if you are selected as a participant, information provided in answer to this question will be made available to the other participants to facilitate networking at the Ideas Lab meeting. (limit: 200 words)

Q2. How do you see your expertise and interests contributing to realizing the goal of this Ideas Lab solicitation? Please frame your answer to explain your interests to an audience with a potentially different expertise to your own. (limit: 150 words)

Q3. Briefly summarize the approach of the main technical, technological, technology validation and translation or other contribution that you plan to propose to solve the challenges posed in this Ideas Lab. Please frame your answer in the context of specific relevant low-latency vertical application(s) of 5G/Next-G networks. (limit: 150 words)

Page Two:

Your responses (of no more than 100 words each) to the following questions will help assess your suitability (unrelated to your R&D/technology development track record) for the innovative and collaborative setting of the Ideas Lab.

Q4. Collaborative teamwork where everyone is regarded and respected as equal is essential to the success of an Ideas Lab. What is your approach to teamwork and what do you regard as your strengths with respect to collaborative teamwork? (100 words)

Q5. How would you explain your area of interest (as it pertains to this workshop) to individuals with expertise different than your own? (100 words)

Q6. How do you deal with potential conflict when adapting your ideas to fit into something more community driven? (100 words)

Q7. The Ideas lab is especially suited to individuals who can step outside their own area of expertise or interest, are positively driven, collaborative, enjoy creative activity, and can think innovatively. It is an intensive setting requiring you to develop novel approaches over several days with individuals you may not have known previously. How do you consider yourself suited? (100 words)

Q8. What do you hope to gain by participating in this Ideas Lab workshop, personally and professionally? (100 words)

Applicants must include a **Biographical Sketch** and a **Current and Pending (Other) Support** document (prepared in accordance with standard NSF formatting guidelines, available at https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg).

No appendices or supplementary documents may be submitted.

Submission of the preliminary proposal will be considered an indication of availability to attend and participate in the full duration of the in-person Ideas Lab workshop (3 days long) and the preceding and follow-up virtual meetings. Selected participants will be notified, and logistics arranged for travel to, and participation in, the Ideas Lab. Following the conclusion of the Ideas Lab workshop, NSF program staff will invite the submission of full proposals related to one or more of the ideas developed during the Ideas Lab.

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

- 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.

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 Research.gov. PAPPG Chapter II.E.3 provides additional information on collaborative proposals.

See PAPPG Chapter II.D.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.

Full proposals based on project ideas developed through interactions at the Ideas Lab workshop should conform to the project outline developed at the conclusion of the workshop. If substantive changes are contemplated, an NSF Program Director should be contacted for guidance.

Proposal Set-Up: Select "Prepare New Full Proposal" in Research.gov. Search for and select this solicitation title in Step 1 of the Full Proposal wizard. The information in Steps 2 and 3 are pre-populated by the system.

Title: The title format is "Ideas Lab: Breaking Low:" followed by a descriptive title. Please note that if submitting via Research.gov, the system will automatically prepend the title with "Ideas Lab:".

Project Description: Ideas Lab full proposals must clearly identify outcomes and deliverables from the proposed work and include a project schedule with milestones.

Additionally, a roadmap (with a timeline) with sufficient details on plans for potential follow-up activities such as technology translation and standardization of R&D innovations resulting from the Ideas Lab project is highly encouraged (in addition to the project schedule).

Other Supplementary Documents: The following special information must be provided as a Supplementary Document (single combined file). This information is not considered part of the 15-page project description limitation but should not exceed a total of 6 pages.

All proposals must include a management plan including a 1) list of project personnel, including their affiliation, expertise and project roles; 2) plan for team coordination and project management; 3) detailed project schedule.

Projects that will be utilizing the NSF-funded or other research platforms (e.g., PAWR platforms) or other shared use facilities are strongly encouraged to include letters of collaboration indicating the scope of collaboration and that access is available to the facility and fits within the timeline of the proposed research.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Budget Preparation Instructions:

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

C. Due Dates

- **Preliminary Proposal Due Date(s)** ***(required)*** (due by 5 p.m. submitter's local time):

  April 18, 2024

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

  September 30, 2024

D. Research.gov/Grants.gov Requirements

For Proposals Submitted Via Research.gov:

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/ProposalPreparationa For Research.gov user support, call the Research.gov Help Desk at 1-800-381-1532 or e-mail rgov@nsf.gov. The Research.gov Help Desk answers general technical questions related to the use of the Research.gov 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: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 Research.gov for further processing.

The NSF Grants.gov Proposal Processing in Research.gov informational page provides submission guidance to applicants and links to helpful resources including the NSF Grants.gov Application Guide, Grants.gov Proposal Processing in Research.gov how-to guide, and Grants.gov Submitted Proposals Frequently Asked Questions. Grants.gov proposals must pass all NSF pre-check and post-check validations in order to be accepted by Research.gov at NSF.

When submitting via Grants.gov, NSF strongly recommends applicants initiate proposal submission at least five business days in advance of a deadline to allow adequate time to address NSF compliance errors

and resubmissions by 5:00 p.m. submitting organization's local time on the deadline. Please note that some errors cannot be corrected in Grants.gov. Once a proposal passes pre-checks but fails any post-check, an applicant can only correct and submit the in-progress proposal in Research.gov.

Proposers that submitted via 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 *Leading the World in Discovery and Innovation, STEM Talent Development and the Delivery of Benefits from Research - NSF Strategic Plan for Fiscal Years (FY) 2022 - 2026*. 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.D.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.D.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 other underrepresented groups 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

Full proposals must clearly address the following solicitation-specific review criteria through well-identified proposal elements:

(1) Does the proposal clearly identify the need for millisecond-range E2E latencies for specific vertical use cases and key technical and/or technological hurdles to achieving them in current 5G/Next-G cellular and/or WLAN designs?

(2) Are the proposed R&D and at-scale testbed and/or pilot demonstration plans clearly aimed at overcoming the identified technical and/or technological barriers?

(3) If successful, how will the project impact Next-G wireless landscape and/or low-latency vertical markets?

In addition, full proposals derived from the Ideas Lab will be evaluated to determine:

- whether the scientific and/or engineering themes/objectives in the proposal are congruent with the ideas presented at the Ideas Lab; and
- whether any significant changes in project scope or resources from those presented at the Ideas Lab have been justified.

Full proposals submitted in response to this program solicitation will be reviewed internally by the cognizant NSF Program Officers, the Ideas Lab mentors, and other external reviewers, as appropriate.

B. Review and Selection Process

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

The Ideas Lab review and selection process is outlined in PAPPG Chapter II.F.6.

Preliminary Proposal Review: Preliminary proposals will be reviewed by a Selection Panel via a panel managed by the PDs. Up to 35 applicants will be selected for participation in the Ideas Lab.

Full Proposal Review: Invited full proposals will be reviewed internally by the cognizant NSF Program Officers, the Ideas Lab panelists, and other external reviewers, as appropriate.

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 proposers whether their proposals have been declined or recommended for funding within six months. Large or particularly complex proposals or proposals from new recipients 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 or the Division of Acquisition and Cooperative Support 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 an NSF Grants and Agreements Officer. 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.

Administrative and National Policy Requirements

Build America, Buy America

As expressed in Executive Order 14005, Ensuring the Future is Made in All of America by All of America's Workers (86 FR 7475), it is the policy of the executive branch to use terms and conditions of Federal financial assistance awards to maximize, consistent with law, the use of goods, products, and materials produced in, and services offered in, the United States.

Consistent with the requirements of the Build America, Buy America Act (Pub. L. 117-58, Division G, Title IX, Subtitle A, November 15, 2021), no funding made available through this funding opportunity may be obligated for an award unless all iron, steel, manufactured products, and construction materials used in the project are produced in the United States. For additional information, visit NSF's Build America, Buy America webpage.

C. Reporting Requirements

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

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

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

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

VIII. Agency Contacts

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

General inquiries regarding this program should be made to:

- Sudharman Jayaweera Kankanamge, telephone: (703) 292-2828, email: sjayawee@nsf.gov
- Jemin George, telephone: (301) 394-3977, email: jgeorge@nsf.gov
- Huaiyu Dai, telephone: (703) 292-4568, email: hdai@nsf.gov
- Alhussein A. Abouzeid, telephone: (703) 292-7855, email: aabouzei@nsf.gov

For questions related to the use of NSF systems contact:

- NSF Help Desk: 1-800-381-1532
- 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.F.7 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** (NSF Information Center)**:** (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**

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

  or telephone: (703) 292-8134
- **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 proposers 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 proposers 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 System of Record Notices, NSF-50, "Principal Investigator/Proposal File and Associated Records," and NSF-51, "Reviewer/Proposal File and Associated Records." 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
Policy Office, Division of Institution and Award Support
Office of Budget, Finance, and Award Management
National Science Foundation
Alexandria, VA 22314

National Science Foundation, 2415 Eisenhower Ave Alexandria, VA 22314
Tel: (703) 292-5111,