Principles and Practice of Scalable Systems (PPoSS)

PROGRAM SOLICITATION
NSF 22-507

REPLACES DOCUMENT(S):
NSF 21-513

National Science Foundation

Directorate for Computer and Information Science and Engineering
Division of Computing and Communication Foundations
Office of Advanced Cyberinfrastructure
Division of Computer and Network Systems
Division of Information and Intelligent Systems

Intel Corporation

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

January 24, 2022

Planning grants and LARGE grants

January 23, 2023

Fourth Monday in January, Annually Thereafter

LARGE grants only

IMPORTANT INFORMATION AND REVISION NOTES

- New research area: Machine Programming (Section II.A.).
- For FY 2022 only: LARGE proposals that choose Machine Programming as one of the four research areas and are interested in co-funding from Intel may submit the proposal for consideration in the NSF/Intel Partnership on Machine Programming. (Section II.C.)
- Cross-cutting criteria are clarified (Section I).
- Purpose of Planning and LARGE projects is clarified (Section II.B.).
- Project Description (Section V.A.) for Planning and LARGE proposals is clarified.
- Page limit for LARGE proposals is revised to 20 pages
- Revised PI eligibility criteria.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 22-1), which is effective for proposals submitted, or due, on or after October 4, 2021.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Principles and Practice of Scalable Systems (PPoSS)

Synopsis of Program:

A key focus of the design of modern computing systems is performance and scalability, particularly in light of the limits of Moore's Law and Dennard scaling. To this end, systems are increasingly being implemented by composing heterogeneous computing components and continually changing memory systems as novel, performant hardware surfaces. Applications fueled by rapid strides in machine learning, data analysis, and extreme-scale simulation are becoming more domain-specific and highly distributed. In this scenario, traditional boundaries between hardware-oriented and software-oriented disciplines are increasingly blurred.

Achieving scalability of systems and applications will therefore require coordinated progress in multiple disciplines such as computer architecture, high-performance computing (HPC), machine programming, programming languages and compilers, security and privacy, systems, and theory and algorithms. Cross-cutting concerns such as performance, correctness and accuracy, and heterogeneity must be taken into account from the outset in all aspects of systems and application design and implementation.

The aim of the Principles and Practice of Scalable Systems (PPoSS) program is to support a community of researchers who will work symbiotically across the multiple disciplines above to perform basic research on scalability and correctness and accuracy of modern applications, systems, and toolchains built on heterogeneous architectures. The intent is that these efforts will foster the development of principles that lead to rigorous and reproducible artifacts for the design and implementation of large-scale systems and applications spanning the full hardware/software stack. Importantly, as described below, **PPoSS specifically seeks to fund projects that span the entire hardware/software stack** and that lay the foundations for sustainable approaches for implementing performant, scalable, and correct and accurate computing applications that run on heterogeneous platforms.

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.

- Anindya Banerjee, Program Director, CISE/CCF, telephone: (703) 292-7885, email: abanerje@nsf.gov
- Damian Dechev, Program Director, CISE/CCF, telephone: (703) 292-8910, email: ddechev@nsf.gov
- Wei Ding, Program Director, CISE/IIS, telephone: (703) 292-8017, email: weiding@nsf.gov
- Funda Ergun, Program Director, CISE/CCF, telephone: (703) 292-2216, email: fergun@nsf.gov
- Alexander Jones, Program Director, CISE/CNS, telephone: (703) 292-8950, email: alejones@nsf.gov
- Tevfik Kosar, Program Director, CISE/OAC, telephone: (703) 292-7992, email: tkosar@nsf.gov
- Mimi M. McClure, Program Director, CISE/CNS, telephone: (703) 292-5197, email: mmcclure@nsf.gov
- Yuanyuan Yang, Program Director, CISE/CCF, telephone: (703) 292-8067, email: yyang@nsf.gov
- Melissa Cowan, Program Director, Intel Labs., telephone: (503) 264-7469, email: melissa.a.cowan@intel.com
- Justin Gottschlich, Research Director, Intel Labs, telephone: (408) 765-3783, email: justin.gottschlich@intel.com

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

- 47.070 --- Computer and Information Science and Engineering

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 17

Planning Grants: Approximately 4 awards will be made in FY 2022, pending availability of funds and quality of proposals received.

LARGE Grants: Approximately 4 awards will be made each year in FY 2022, FY 2023, and FY 2024.

LARGE Grants joint with Intel: 1 award jointly funded by NSF and Intel, specifically in the Machine Programming research area, is anticipated in FY 2022.

Anticipated Funding Amount: $66,000,000

Planning Grants: Up to $250,000 per award with duration up to 1 year.

LARGE Grants: Up to $1,000,000 per year with duration up to 5 years.

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

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 labs, professional societies and similar organizations in the U.S. associated with educational or research activities.

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 Intel and Affiliated Individuals in Proposals:

Guidelines for Intel:

Intel is not permitted to participate in proposals to the program.

Guidelines for Individuals Affiliated with Intel:

Individuals affiliated with Intel 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 Intel. Specifically:

- Such individuals may not participate in their capacity with Intel.
- 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: 3

An investigator may participate as PI, co-PI, or Senior Personnel in no more than two planning grant proposals and in no more than one LARGE proposal submitted to each deadline listed above.

An investigator cannot be PI, co-PI, or Senior Personnel on more than two Planning awards and one LARGE award through the life of this program from FY 2020 to FY 2024.

These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently.

In the event that an individual exceeds this limit, the corresponding proposal on which the individual serves as PI, co-PI, or Senior Personnel, will be returned without review. **No exceptions will be made.**

Proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by NSF.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

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

B. Budgetary Information

- **Cost Sharing Requirements:**

  Inclusion of voluntary committed cost sharing is prohibited.

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

  Not Applicable

- **Other Budgetary Limitations:**

  Other budgetary limitations apply. Please see the full text of this solicitation for further information.

C. Due Dates

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

  January 24, 2022

  Planning grants and LARGE grants

  January 23, 2023

Fourth Monday in January, Annually Thereafter

LARGE grants only

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:

Standard NSF reporting requirements apply.

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I. INTRODUCTION

Computing systems have undergone a fundamental transformation from the relatively isolated single-processor systems to large-scale distributed and networked systems within a span of a few decades. During this period, the observations by Gordon Moore about the regular and timely increase in computational capacity and Robert Dennard about the proportional scaling of size and power of transistors have largely held true. With the imminent end of Moore's Law and Dennard scaling, continued scalability of applications has become a major concern. Furthermore, over the years, the use of parallel and distributed systems has expanded beyond traditional supercomputing applications (i.e., scientific simulation) to providing the essential computing infrastructure that advance artificial intelligence (AI) and machine learning (ML), large-scale communication networks (e.g., social media), smart and connected communities, etc. However, the field of parallel and distributed systems faces a number of existing and emerging challenges that must be overcome to meet the diverse and rapidly increasing computational requirements of new, larger, highly distributed applications.

Several reports, including "Future Directions for NSF Advanced Computing Infrastructure to Support U.S. Science and Engineering in 2017-2020"; "Cyberinfrastructure for 21st Century Science and Engineering"; and the recently-issued "Future Advanced Computing Ecosystem (FACE), A Strategic Plan", have outlined the need for computational systems that enable emerging, large-scale applications without the benefit of Dennard scaling (the "post-Moore's Law era"). Furthermore, their conclusions align with Administration and Congressional priorities on basic and applied research investments in computing.

The objective of the Principles and Practice of Scalable Systems (PPoSS) program, therefore, is to build a community of researchers who will work symbiotically to perform basic research on scalability, performance, and correctness and accuracy of modern applications, systems, and toolchains built on heterogeneous architectures. PPoSS expects coordinated progress at the intersection of multiple disciplines including, but not limited to, computer architecture, HPC, programming languages and compilers, machine programming, security and privacy, systems, and theory and algorithms. **All the cross-cutting concerns** listed below must be addressed from the outset in all aspects of systems design and implementation, and must be tackled with respect to the **full hardware and software stack**:

- Scalability and performance (including, but not limited to, portability, resource usage, and energy efficiency);

- Correctness and accuracy (including, but not limited to, emerging techniques for programming, analysis, testing, debugging, probabilistic reasoning and inference, verification); and
- Heterogeneous architectures (including, but not limited to, systems with many cores and heterogeneous computing components such as Graphics Processing Units (GPUs), Tensor Processing Units, Field-Programmable Gate Arrays (FPGAs), continually changing memory systems (e.g., Non-Volatile Random Access Memories).

The intent is that these efforts will foster the development of principles that lead to rigorous and reproducible methodologies for the design and implementation of large-scale systems while simultaneously incorporating the cross-cutting concerns listed above.

II. PROGRAM DESCRIPTION

Systems incorporating a variety of specialized components form heterogeneous platforms that are very powerful but also make application development more difficult. While current solutions include a transition to new computational fabrics that may offer future increases in performance, the highest-performance computing systems are still very specialized; i.e., customized in the hardware, algorithms, and abstractions underlying the software to fit the exact organization and requirements of the application at hand. This pressure towards application-specific design is compounded by the expansion of computing into new environments and domains, such as digital agriculture (in which applications are highly distributed and decentralized) and involve both localized sensing computations on thousands – or even millions – of low-power edge devices and predictive simulations at landscape or global scale running in massive data centers. Such applications will challenge future systems to simultaneously compose and orchestrate both small and large devices alike. These applications will also push computing towards new abstractions, algorithms, and systems stacks, such as those integrating sensing and AI/ML, that are of increasing importance to computer science. In addition to seeking only the traditional goals of performance and scalability (latency, throughput, etc.), energy efficiency, and reliability, there is increased demand for these solutions to facilitate reasoning about accuracy, correctness, security, and privacy, which have become central system goals. The methodology for building these systems may therefore require new automated analyses and correct-by-construction development methods that address these goals from the outset of the design process. In summary, it is expected that the next generation of parallel and distributed computing systems will include domain-specific solutions and will combine a heterogeneous mix of computational patterns, algorithms, and hardware to achieve a set of goals that go beyond traditional systems aims to meet society's needs for more scalable, energy-efficient, reliable, verifiable, and secure computing systems.

A recent NSF-supported workshop, brought together researchers from academia, government, and industry to discuss future directions in parallel and distributed computing with an underlying emphasis on sustaining scalable system performance in modern computing environments. The workshop report identifies a variety of challenges in systems design and implementation that have been exacerbated by the rapid evolution and proliferation of machine/deep learning and AI techniques. Large-scale systems that increasingly serve domain-specific applications are distributed (e.g., distributed machine-learning systems), and are composed of heterogeneous computing components. Applications supported by these systems now expand beyond traditional supercomputing applications to encompass, for example, data-driven applications, learning-based applications, and communication networks.

The consequent research challenges are complex. First, the post-Moore's Law era necessitates performance improvement by exploiting heterogeneous hardware accelerators, and innovative architectural platforms. Second, new abstractions that enable scalability should explore *all* levels of the hardware/software stack and should simultaneously facilitate improved reasoning about key systems properties such as correctness and accuracy. Third, scalability must be evaluated end-to-end, that is, with respect to the *full* hardware/software stack because innovations and breakthroughs in specific parts of the hardware/software stack may have effects that percolate throughout the system.

With these challenges in mind, the scope of PPoSS includes, but is not limited to, the research areas mentioned below (Section II.A). All projects must ensure that they cover multiple **(at least four)** research areas and have senior personnel with commensurate expertise. Moreover, **projects must encompass all the cross-cutting concerns (Section I) with respect to the full hardware and software stack**.

II.A. Research Areas

Illustrative, but non-exhaustive, research areas are discussed below. As traditional boundaries between the topics get increasingly blurred in the post-Moore's Law era, there is a clear need for the corresponding communities to meaningfully collaborate.

Computer Architecture: Recent architecture research has explored point solutions in the form of accelerators for individual computations, but many challenges arise when deploying such specialization and heterogeneity in extreme scale systems where multiple accelerators co-exist. There is a need for principles that guide architectures when considering scaling to full systems that deploy multiple accelerators and application-specializations in compute, memory, communications, and storage for a large number of application domains. In tandem, there is a need to develop principles that guide the design of the hardware so that it is amenable to easily programmable software interfaces. Models of special-purpose architectures that will result in general-purpose design methodologies and tools without the inefficiencies associated with today's general-purpose architectures and that can quickly and cheaply transform an application, domain, or algorithm specification to the required hardware and software stack must also be investigated.

Hardware architecture and higher layers are in scope for PPoSS. Circuit-level implementation and layers below are not in scope for PPoSS.

High-Performance Computing: In modern usage, HPC is interpreted broadly to mean the scale-up of virtually any computational process. HPC techniques are used to scale not only traditional simulations, but also applications in which learning, data analytics, and simulation are combined. There is a need to develop principles of design and implementation to bestow such applications with high performance and extreme scalability, while simultaneously optimizing their power footprints and permitting a broad range of resource usage behaviors that may differ across components of the applications and phases of their workflows. Increasing irregularity of workloads and platforms poses a formidable challenge to performance and scalability, in addition to the cross-cutting concerns mentioned above. Irregularity may arise, for instance, from multiple sources within advanced scientific applications and the cause of irregular workloads may vary across applications -- it may arise owing to the need to run multiple dissimilar operations in parallel, or it may arise owing to trends in modern computer architectures, such as dynamic power management, heterogeneous nodes (e.g., some with GPUs or other accelerators), and deep memory hierarchies. The improvement of scalability of HPC applications that can be gained by utilizing technologies such as deep learning (e.g., to prune the parameter search space in ensembles or potentially replacing parts of the modeling workflow) should also be explored.

Machine Programming: As hardware architecture evolves rapidly and programmers increasingly come from fields removed from computer science, Machine Programming can play a key role in harnessing the full potential of modern computing platforms. Advancements in machine learning and automated reasoning can help deliver a significant degree of automation in producing correct, secure, scalable, portable, and highly adaptable software. Achieving a practical solution may rely on addressing the fundamental challenges of how to provide an interface between the human and the computing system, how to develop techniques to allow computing systems to create and refine algorithms and code, and how to utilize machine learning-based tools to allow the software to adapt to changing conditions. Research is needed to develop new principles in areas such as intentional programming, probabilistic and differentiable programming, and

programming language support for machine learning frameworks and applications. New methods need to be created and integrated to allow for practical and provably correct program transformations and automated semantic program analysis and reasoning.

For FY 2022 only: Proposals responsive to this research area and interested in possible co-funding from Intel must indicate as such, as outlined in Section V.A, Proposal Preparation Instructions, below.

Programming Languages and Compilers: Heterogeneity is one of the thorniest emerging challenges for programming languages and compilers research and takes at least two forms: domain heterogeneity and systems heterogeneity. Domain heterogeneity encompasses applications that themselves span many problem domains and associated computation styles. Systems heterogeneity encompasses systems that themselves consist of a set of devices, each with unique computing interfaces (e.g., CPU versus GPU versus FPGA) and unique physical locations in the overall system, with unique programming interfaces and attributes (e.g., efficiency, reliability, memory consistency models, intentional programming models). A fundamental challenge in this context is to understand interoperability across applications and across devices, its semantics in the presence of extreme variations in abstractions, and how the semantics can be engineered within programming languages and compilers to obtain scalability and correctness across the full hardware/software stack.

Security and Privacy: The techniques used to develop extreme scale systems often neglect safety, security, and privacy concerns in favor of performance and scalability. Emerging domains like edge computing, confidential cloud computing, and secure distributed computation introduce new security vulnerabilities and privacy concerns especially when designed explicitly for, and operated at, extreme scale. Massive-scale edge computing applications (e.g., sensor or video monitoring) require sophisticated computations but cannot centralize the gathered data due to communication costs. A difficult challenge is to develop extreme-scale algorithms that can address the security and privacy issues involved. In the context of cloud computing, there are significant concerns about security and privacy. New ideas in cryptography and system/hardware design are enabling much more efficient confidential computing methods, some of which are already being adopted by cloud providers. Research should explore how to run extreme-scale applications in these environments and how to use extreme scale to accelerate confidential computing techniques. Finally, in the context of distributed computations, there are many techniques that are capable of providing strong security and privacy guarantees even if some users or servers are compromised. Research should therefore explore new algorithms and system features that can enable distributed computation at scale and verify that such computation is security and privacy-preserving.

Systems: The increasing heterogeneity of hardware platforms and the shift towards more domain-specific systems are creating new challenges at all levels of the systems stack, including networks and operating systems. First, with changes in hardware platforms, correctness, robustness, and accuracy have become major concerns: programs often give unexpected results on new platforms owing to differences in hardware semantics (such as various memory types and memory consistency models). Second, the rise of heterogeneous hardware and domain-specific libraries means that applications are increasingly composed of many separately designed, domain-specific components. Optimizing across components is increasingly important to achieve maintainable and adaptive scalability across the full hardware/software stack. Third, security is an understudied aspect of extreme-scale systems that is critical in de-centralized or privacy-sensitive settings such as edge computing and the public cloud. Security, in this specific context, is aligned with correctness to ensure that existing applications behave well in the presence of adversary-controlled input data. Research should aim to produce principles of large-scale system design that enable use of components that come from multiple, possibly untrusted third parties, yet also satisfy the cross-cutting concerns.

Theory and Algorithms: One of the biggest challenges is to develop appropriate computational models for the many new features of modern large-scale systems. These features include complicated memory hierarchies, new memory technologies, heterogeneity, support for remote direct memory access, frequency scaling, smart memories, energy-saving modes, and application-specific hardware. A second challenge involves providing fault tolerance in extreme-scale distributed systems. As systems get larger, it becomes impractical to ensure that all components continuously function without faults. The challenge is to develop a theory of reliability that addresses different kinds of faults. A third challenge is to consider environments with changing resources and permit multiple shared users. Much existing theory on parallel algorithms assumes full control over a fixed collection of resources, but this assumption can limit applicability in the context of cloud resources, faults, and more dynamic workloads. Existing theories of distributed, parallel, streaming, and sub-linear algorithms should be adapted and extended as necessary and appropriate to address the challenges listed above.

II.B. Planning and LARGE Projects

There are two categories of projects: Planning and LARGE. Both Planning and LARGE projects must describe: (a) at least four research areas, and (b) the targeted distributed applications and the heterogeneous platforms on which the applications run.

The purpose of a Planning project is to demonstrate readiness for a LARGE project. Please note that the Planning proposals described in this solicitation are a solicitation-specific project category and are separate and distinct from the type of proposal described in Chapter II.E.1 of the PAPPG. When preparing a Planning proposal in response to this solicitation, the "Research" type of proposal should be selected in the proposal preparation module in FastLane or Grants.gov. A Planning project must provide a vision together with preliminary research on how it intends to address the cross-cutting concerns (Section I) with respect to the full hardware and software stack. Planning activities may include, but are not limited to, collaborative efforts, development of research infrastructure, organization of workshops etc.

A LARGE project must present a full-scale research project. It must include preliminary evidence that all the cross-cutting criteria (Section I) are met with respect to the full hardware and software stack.

II.C. NSF/Intel Partnership on Machine Programming

The NSF/Intel Partnership on Machine Programming seeks to significantly advance the state of machine programming principles and practices. For FY 2022 a PPoSS proposal submitted to the NSF/Intel Partnership on Machine Programming must have machine programming as one of its four research areas. **The proposal must demonstrate synergy between machine programming and the other three research areas**. Such proposals will be reviewed in a separate panel dedicated to the NSF/Intel Partnership.

The NSF/Intel Partnership on Machine Programming will only accept LARGE proposals.

III. AWARD INFORMATION

Anticipated Type of Award: Standard Grants and Continuing Grants

Estimated Number of Awards: 17

Planning Grants: Approximately 4 awards will be made in FY 2022, pending availability of funds and quality of proposals received.

LARGE Grants: Approximately 4 awards will be made each year in FY 2022, FY 2023, and FY 2024, pending availability of funds and quality of proposals received.

LARGE Grants joint with Intel: 1 award jointly funded by NSF and Intel, specifically in the Machine Programming research area, is anticipated in FY 2022.

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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.
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Who May Serve as PI:

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

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- 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 Intel and Affiliated Individuals in Proposals:

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Intel is not permitted to participate in proposals to the program.

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Individuals affiliated with Intel 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 Intel. Specifically:

- Such individuals may not participate in their capacity with Intel.
- 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: 3

An investigator may participate as PI, co-PI, or Senior Personnel in no more than two planning grant proposals and in no more than one LARGE proposal submitted to each deadline listed above.

An investigator cannot be PI, co-PI, or Senior Personnel on more than two Planning awards and one LARGE award through the life of this program from FY 2020 to FY 2024.

These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently.

In the event that an individual exceeds this limit, the corresponding proposal on which the individual serves as PI, co-PI, or Senior Personnel, will be returned without review. **No exceptions will be made.**

Proposals submitted in response to this solicitation may not duplicate or be substantially similar to other proposals concurrently under consideration by NSF.

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 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 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 the NSF FastLane system. PAPPG Chapter II.D.3 provides additional information on collaborative proposals.

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

Please note that the Planning proposals described in this solicitation are a solicitation-specific project category and are separate and distinct from the type of proposal described in Chapter II.E.1 of the PAPPG. When preparing a Planning proposal in response to this solicitation, the "Research" type of proposal should be selected in the proposal preparation module in FastLane or Grants.gov.

Proposal title: Proposal titles must indicate the **PPoSS** program followed by a colon and indicate the type of proposal, "**Planning**" or "**LARGE**", followed by a colon, then the title of the project. For example, **PPoSS: Planning: Title** or **PPoSS: LARGE: Title.** For proposals submitted as part of a set of collaborative proposals, all participating institutions should use the same title, which should begin with "Collaborative Research:" for example, **Collaborative Research: PPoSS: LARGE: Title**. For proposals from PIs in institutions that have RUI (Research in Undergraduate Institutions) eligibility, the title should include the keyword RUI, e.g. **PPoSS: Planning: RUI: Title** or **Collaborative Research: PPoSS: LARGE: RUI: : Title**.

Proposals intended for the NSF/Intel Partnership on Machine Programming, should indicate so in the proposal title as follows: **PPoSS: LARGE: Intel: Title** or **Collaborative Research: PPoSS: LARGE: Intel: Title**.

Project Summary: The Project Summary consists of an overview, a statement on the intellectual merit of the proposed activity, and a statement on the broader impacts of the proposed activity.

Please provide between 2 and 6 keywords at the end of the overview in the Project Summary. The keywords should describe the main scientific/engineering areas explored in the proposal. Keywords should be prefaced with "Keywords" followed by a colon, and the keywords should be separated by semi-colons. Keywords should be of the type used to describe research in a journal submission. They should be included at the end of the overview in the project summary and might appear, for example, as **Keywords: energy-aware computing; formal logic; machine programming; computer graphics; sensor networks; information visualization; privacy.**

Project Description:

Describe the research and education activities to be undertaken in **up to 15 pages for Planning proposals, and up to 20 pages for LARGE proposals**.

This section should be completed according to the general guidelines detailed in the NSF PAPPG, including the requirement for a separate section labeled "Broader Impacts." In addition:

The Project Description must contain a section titled "Research Areas" that must:

1. Explicitly state and motivate **at least four research areas** covered (along with senior personnel with commensurate expertise);
2. Describe the targeted distributed applications and systems, and the heterogeneous platforms on which they run; and
3. Define relevant notions of scale and describe how scalability will be theoretically and experimentally evaluated for the targeted distributed applications and systems and heterogeneous platforms in (2) with respect to the **full hardware/software stack.**

The Project Description must contain a section titled "Cross-cutting concerns" that addresses all the cross-cutting criteria (Section I).

A Planning proposal must include, in this section, a vision of how it plans to address the cross-cutting concerns to establish readiness for a LARGE proposal: in particular, it must provide preliminary research on how it plans to achieve (4-6) below.

In addition to (1-3) above, a LARGE proposal must include in this section:

4. Preliminary evidence of end-to-end scalability of the targeted applications in (2) above, based on proposed theories and abstractions;
5. Preliminary demonstration of verified, end-to-end correctness and accuracy of the targeted applications in (2) above; and
6. Preliminary demonstration of how (4) and (5) are handled in the presence of heterogeneous architectures.

The Project Description must contain a section titled "Evaluation Plan" that (a) includes a timeline of proof-of-concept implementations of the key components; and (b) outlines how the project's success will be measured.

A proposal that does not include separate sections titled "Research Areas", "Cross-cutting Concerns", and "Evaluation Plan" that explicitly address the points above will be returned without review.

Supplementary Documents: In the Supplementary Documents Section, upload the following information where relevant:

1. *List of Project Personnel and Partner Institutions (Note: In collaborative proposals, the lead institution should provide this information for all participants)*:

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

1. Mary Smith; XYZ University; PI
2. John Jones; University of PQR; Senior Personnel
3. Jane Brown; XYZ University; Postdoc
4. Bob Adams; ABC Community College; Paid Consultant
5. Susan White; DEF Corporation; Unpaid Collaborator
6. Tim Green; ZZZ University; Subawardee

2. *Management and Coordination Plans for LARGE projects (required)*:

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

Every LARGE proposal must contain a clearly labeled "Management and Coordination Plan", which includes: 1) the specific roles of the PI, co-PIs, other senior personnel, and paid consultants at all organizations involved to demonstrate that the project personnel have distinct but complementary expertise at different levels of the hardware/software stack, and in at least four of the program's research areas; 2) how the project will be managed across organizations and expertise; 3) identification of the specific coordination mechanisms that will enable cross-organization and/or cross-expertise scientific integration and achieve synergy within the team; and 4) pointers to the budget line items that support these management and coordination mechanisms.

If a LARGE proposal does not include a Collaboration Plan of up to 3 pages addressing (1)-(4) above, that proposal will be returned without review.

PIs submitting to the NSF/Intel Partnership on Machine Programming must review the relevant narrative in Section VII.B. and Section VII.C. of this Solicitation.

3. *Data Management Plan (required):*

Proposals must include a Supplementary Document of no more than two pages labeled "Data Management Plan". This Supplementary Document should describe how the proposal will conform to NSF policy on the dissemination and sharing of research results.

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

For additional information on the Dissemination and Sharing of Research Results, see: https://www.nsf.gov/bfa/dias/policy/dmp.jsp.

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

4. *Documentation of Collaborative Arrangements of Significance to the Proposal:*

Any substantial collaboration with individuals not included in the budget should be described in the Facilities, Equipment and Other Resources section of the proposal (see Chapter II.C.2.i of the PAPPG) and documented in a letter of collaboration from each collaborator. Such letters should be provided in the Supplementary Documentation section and follow the format instructions specified in Chapter II.C.2.j. Collaborative activities that are identified in the budget should follow the instructions in Chapter II.D.3.

5. *Other Specialized Information:*

RUI Proposals: PIs from predominantly undergraduate institutions should include a Research in Undergraduate Institutions (RUI) Impact Statement and Certification of RUI Eligibility in this section.

No other Supplementary Documents, except as permitted by the NSF PAPPG, are allowed.

Single Copy Documents:

Collaborators and Other Affiliations Information:

Proposers should follow the guidance specified in Chapter II.C.1.e of the NSF PAPPG.

Note the distinction to item (1) under Supplementary Documents above: the listing of all project participants is collected by the project lead and entered as a Supplementary Document, which is then automatically included with all proposals in a project. The Collaborators and Other Affiliations are entered for each participant within each proposal and, as Single Copy Documents, are available only to NSF staff.

Submission Checklist:

In an effort to assist proposal preparation, the following checklist is provided as a reminder of some important items that should be checked before submitting a proposal to this solicitation. For the items marked with (RWR), the proposal will be returned without review if the required item is non-compliant at the submission deadline. Note that these are requirements unique to this solicitation; for other return without review requirements, see the PAPPG.

- (RWR) **As per additional solicitation-specific criteria any proposal that does not include separate sections titled "Research Areas", "Cross-cutting Concerns", and "Evaluation Plan", and which do not explicitly address the points in Section V.A. (Project Description) will be returned without review.**
- (RWR) A LARGE proposal must include a **Management and Coordination plan** (3-page limit) to be submitted as a Supplementary Document.
- (RWR) Eligibility criteria must be followed. (See Eligibility Information.)
- The last line of the overview section in the Project Summary should consist of the word "Keywords" followed by a colon and between 2-6 keywords, separated by semi-colons.
- Page limit of LARGE proposals is 20 pages.

Proposals that do not comply with the requirements marked as RWR will be returned without review.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Other Budgetary Limitations:

- LARGE grants: Proposal budgets must be up to $1,000,000 per year and must not exceed $5,000,000 in total.
- Planning grants: Proposal budgets must not exceed $250,000.

Budget Preparation Instructions:

- Budgets for projects should include funding for one or more project representatives (PI/co-PI/senior researcher or NSF-approved replacement) to attend NSF PI meetings that are expected to be held annually after the beginning of the award.
- The budget for a proposal submitted to the NSF/Intel Partnership on Machine Programming should include all necessary project funds without regard to the two funding organizations; NSF and Intel will inform selected PIs of the breakdown in funding between the two organizations, and will request revised budgets at that point. For the Intel portion of the budget, yearly funds must be included to travel to an Intel site (e.g., Santa Clara, CA, or Hillsboro, OR) for the semi-annual workshops.

C. Due Dates

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

  January 24, 2022

  Planning grants and LARGE grants

  January 23, 2023

  Fourth Monday in January, Annually Thereafter

  LARGE grants only

D. FastLane/Grants.gov Requirements

For Proposals Submitted Via FastLane:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: https://www.fastlane.nsf.gov/a1/newstan.htm. For FastLane user support, call the NSF Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov. The NSF 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 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 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

Planning Proposals

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

- Description and motivation of at least four research areas.
- Description of the distributed applications (e.g., within a large datacenter or across datacenters).
- Description of relevant notions of scale along with the vision of how scalability will be theoretically and experimentally evaluated with respect to the full hardware/software stack.
- Vision and preliminary research on all cross-cutting concerns (Section I) and how these will be incorporated across the full hardware/software stack.
- Evaluation plan that includes timeline and outlines success metrics.
- Plans for creating a team of PIs who possess complementary expertise to execute the project.

LARGE Proposals

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

- Description and motivation of at least four research areas.
- Description of targeted distributed applications (e.g., within a large datacenter or across datacenters).
- Description of relevant notions of scale along with preliminary research on how scalability will be theoretically and experimentally evaluated with respect to the full hardware/software stack.
- Preliminary research and preliminary evidence in support of all cross-cutting concerns (Section I) and how these will be incorporated across the full hardware/software stack.
- Evaluation plan that includes timeline and outlines success metrics.
- Demonstration of the team's complementary expertise and synergy.

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by Ad hoc Review and/or Panel Review, or Intel internal review for proposals submitted to NSF/Intel Partnership on Machine Programming.

NSF/Intel Partnership on Machine Programming

For proposals submitted to the NSF/Intel Partnership on Machine Programming, Intel and NSF will each conduct separate proposal reviews. Intel representatives may act as observers in the NSF review process for such proposals. For Intel, internal review will be conducted. Proposals, unattributed reviews, and panel summaries will be shared securely with Intel as appropriate. Upon conclusion of the separate reviews, award recommendations will be coordinated by a Joint NSF and Intel Working Group (JWG) comprising personnel from both NSF and Intel. The JWG will recommend meritorious proposals for award.

Intel has a strong commitment to broadening participation, as does NSF (https://www.nsf.gov/od/broadeningparticipation/bp.jsp), and will provide the same considerations as NSF to the diversity of the proposer team in the evaluation of the proposals. No separate Broadening Participation in Computing (BPC) plans are required.

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

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

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

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

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

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

B. Award Conditions

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

*These documents may be accessed electronically on NSF's Website at https://www.nsf.gov/awards/managing/award_conditions.jsp?org=NSF. Paper copies may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-8134 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:

NSF PI meetings are expected to be held annually between FY 2022 and FY 2027 for LARGE project awardees at locations within the continental United States. One PI (or co-PI) of every funded LARGE project is expected to attend these meetings.

NSF/Intel Partnership on Machine Programming

An award that is jointly supported by NSF and Intel will be funded through separate NSF and Intel funding instruments. NSF awards will be made as continuing or standard grants. Intel awards will be made as Intel agreements (i.e., Contracts, Grants, or Gifts). NSF and Intel will manage their respective awards/agreements in accordance with their own guidelines and regulations.

1. **Workshops:** Independent of the annual NSF PI meetings, Intel separately may organize semi-annual and/or annual workshops which can be open to all PPoSS program awardees. The workshop can bring together the academic community involved in the NSF/Intel Partnership on Machine Programming, along with interested NSF and Intel personnel. While awardees not funded by Intel may be invited by Intel to the workshop, their attendance is not required. Intel will work with academic leadership to organize these events. They will involve reviews of the research underway in each project along with presentations from Intel on technical areas of interest related to each awarded project. Ample time will be provided for face-to-face interaction between participants in these retreats.

2. **Intellectual property, publishing, and licensing:** All awardees will agree to distribute all source code that has been authored while working on an NSF/Intel Partnership on Machine Programming award under a Berkeley Software Distribution (BSD), Apache or other equivalent open-source license. Software licenses that require as a condition of use, modification and/or distribution that the software or other software incorporated into, derived from or distributed with the software be licensed by the user to third-parties for the purpose of making and/or distributing derivative works are not permitted. Licenses not appropriate thus include any version of GNU's General Public License (GPL) or Lesser/Library GPL (LGPL), the Artistic License (e.g., PERL), and the Mozilla Public License.

Exceptions to this policy may be granted by NSF and Intel to address the problem of participation in established open-source software projects or standards already licensed under GPL, LGPL, or other copyleft open-source licenses.

Projects that generate data or software in performing the work under an award agree not to incorporate any third-party code or background intellectual property, except by separate prearrangement with NSF and Intel, into this data or software that would limit or restrict its ability to be distributed under an open source license.

Awardees may file patent applications, providing that they grant to Intel 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 joint award. [Note: The Bayh-Dole Act provides similar rights to the U.S. Government for patents on inventions made under Federal funding.] Intel's license will include, at its discretion, its subsidiaries and contractors to the extent that their use is specifically in connection with Intel's products and/or services. Awardees shall grant the license to Intel unless Intel opts to decline the license. Such license shall not extend to awardees' background intellectual property; however, awardees and Intel may negotiate, voluntarily, in

good faith, a mutually acceptable resolution to background intellectual property, if desired. NSF shall neither enforce nor participate in any such negotiations between Intel and awardees, nor will any funds provided by NSF to the awardee be contingent upon such negotiations. No rights or licenses are granted by Intel. 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.

3. **Program management:** Intel may require deliverable reports to monitor project progress. Annual on-site reviews may be conducted jointly by NSF and Intel. Intel may lead the organization of monthly or bimonthly (every other month) phone calls with project teams; NSF may participate in these calls at its discretion. NSF and Intel may request visits to the research institutions or may ask PIs to visit NSF or Intel. Intel will support all travel-related expenses for PIs, co-PIs, and students as well as meeting expenses for any additional meetings/retreats (beyond the aforementioned Annual Workshops) that Intel requests and organizes in association with this solicitation.

4. **Intel participation in research:** Intel may separately fund its own personnel to directly participate in research funded under the NSF/Intel Partnership on Machine Programming, part-time or full-time, with the universities awarded NSF/Intel Partnership projects. Proposals do not need to budget for the cost of such personnel. These Intel researchers will work alongside the academic researchers, identifying opportunities for technology transfer, and being involved with the projects as advisors or as fellow researchers. Optional deployment of Intel Researchers in Residence (RinR) on campuses will require mutual consent by the Parties and respective awardees for each NSF/Intel Partnership award, and such consent can be withdrawn at any time by the Parties or the respective awardees. Further, Intel may designate one of its more senior, separately-funded researchers to work alongside NSF/Intel Partnership academic lead PIs. He/she would inject a perspective on commercial aspects and help with the day-to-day leadership of the center. He/she would also be responsible for working with the Intel Program Director to oversee the engagement of all other Intel researchers.

NSF/Intel Partnership on Machine Programming

Awardees will be required to include appropriate acknowledgment of NSF and Intel support in reports and/or publications on work performed under the award. An example of such an acknowledgement would be: "This material is based upon work supported by NSF/Intel Partnership on Machine Programming under Award Title and No. [Recipient enters project title and awards number(s)]."

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:

- Anindya Banerjee, Program Director, CISE/CCF, telephone: (703) 292-7885, email: abanerje@nsf.gov
- Damian Dechev, Program Director, CISE/CCF, telephone: (703) 292-8910, email: ddechev@nsf.gov
- Wei Ding, Program Director, CISE/IIS, telephone: (703) 292-8017, email: weiding@nsf.gov
- Funda Ergun, Program Director, CISE/CCF, telephone: (703) 292-2216, email: fergun@nsf.gov
- Alexander Jones, Program Director, CISE/CNS, telephone: (703) 292-8950, email: alejones@nsf.gov
- Tevfik Kosar, Program Director, CISE/OAC, telephone: (703) 292-7992, email: tkosar@nsf.gov
- Mimi M. McClure, Program Director, CISE/CNS, telephone: (703) 292-5197, email: mmcclure@nsf.gov
- Yuanyuan Yang, Program Director, CISE/CCF, telephone: (703) 292-8067, email: yyang@nsf.gov
- Melissa Cowan, Program Director, Intel Labs., telephone: (503) 264-7469, email: melissa.a.cowan@intel.com
- Justin Gottschlich, Research Director, Intel Labs, telephone: (408) 765-3783, email: justin.gottschlich@intel.com

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.

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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.

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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.

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- **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:**

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  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 awardees will be used for program evaluation and reporting within the Executive Branch and to Congress. The information requested may be disclosed to qualified reviewers and staff

assistants as part of the proposal review process; to proposer institutions/grantees to provide or obtain data regarding the proposal review process, award decisions, or the administration of awards; to government contractors, experts, volunteers and researchers and educators as necessary to complete assigned work; to other government agencies or other entities needing information regarding applicants or nominees as part of a joint application review process, or in order to coordinate programs or policy; and to another Federal agency, court, or party in a court or Federal administrative proceeding if the government is a party. Information about Principal Investigators may be added to the Reviewer file and used to select potential candidates to serve as peer reviewers or advisory committee members. See 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