This solicitation has been archived and replaced by NSF 19-598.

NSF/Intel Partnership on Foundational Microarchitecture Research (FoMR)

PROGRAM SOLICITATION
NSF 18-588

REPLACES DOCUMENT(S):
NSF 17-597

National Science Foundation

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

Intel Labs University Collaboration Office

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

November 28, 2018

IMPORTANT INFORMATION AND REVISION NOTES

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

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

NSF/Intel Partnership on Foundational Microarchitecture Research (FoMR)

Synopsis of Program:

The confluence of transistor scaling, increases in the number of architecture designs per process generation, the slowing of clock frequency growth, and recent success in research exploiting thread-level parallelism (TLP) and data-level parallelism (DLP) all point to an increasing opportunity for innovative microarchitecture techniques and methodologies in delivering performance growth in the future.

The NSF/Intel Partnership on Foundational Microarchitecture Research will support transformative microarchitecture research targeting improvements in instructions per cycle (IPC). This solicitation seeks microarchitecture technique innovations beyond simplistic, incremental scaling of existing microarchitectural structures. Specifically, FoMR seeks to advance research that has the following characteristics: (1) high IPC techniques ranging from microarchitecture to code generation; (2) “microarchitecture turbo” techniques that marshal chip resources and system memory bandwidth to accelerate sequential or single-threaded programs; and (3) techniques to support efficient compiler code generation. Advances in these areas promise to provide significant performance improvements that continue the trends characterized by Moore’s Law.

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.

- Yuanyuan Yang, Program Director, CCF, telephone: (703) 292-8910, email: yyang@nsf.gov
- Matt Haycock, Center Executive Sponsor, Vice President, Intel Labs, telephone: (503) 712-2872, email: matthew.haycock@intel.com

- Hong Wang, Center Managing Sponsor, Intel Fellow, Intel Labs, telephone: (408) 653-7075, email: hong.wang@intel.com
- Jeff Parkhurst, Center Program Director, Intel Labs, telephone: (916) 356-2508, email: jeff.parkhurst@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 or Intel Agreement (i.e., Contract, Grant or Gift)

Estimated Number of Awards: 5

Approximately 5 awards are anticipated, each up to $500,000 and up to 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: $2,500,000

subject to the availability of funds and quality of proposals 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.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

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

This limit on the number of proposals per PI, co-PI, or senior personnel applies only to this NSF/Intel Partnership on Foundational Microarchitecture Research (FoMR) program solicitation.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

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

B. Budgetary Information

- **Cost Sharing Requirements:**

Inclusion of voluntary committed cost sharing is prohibited.

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

  Not Applicable

- **Other Budgetary Limitations:**

  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):

  November 28, 2018

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria apply.

Award Administration Information

Award Conditions:

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

Reporting Requirements:

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

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I. INTRODUCTION

Today’s applications and language runtime environments, which employ and host highly demanding algorithms across multiple domains and span both server- and client-side deployments, yield significant opportunity for microarchitecture technique innovations.

The confluence of transistor scaling, increases in the number of architecture generations per process generation, the slowing of clock frequency growth, and recent success in research exploiting TLP and DLP all point to an increasing opportunity for innovative microarchitecture techniques in delivering performance growth in the future.

Instruction-level parallelism (ILP) improvements face fundamentally difficult constraints, e.g., branch misprediction and cache misses. Overcoming these constraints, while difficult, promises to bring substantial increases in IPC.

The NSF/Intel Partnership on Foundational Microarchitecture Research will support microarchitecture research targeting transformative improvements in IPC. This solicitation seeks microarchitecture technique innovations beyond simplistic, incremental scaling of the existing microarchitectural structures. Specifically, FoMR seeks to advance research that has the following characteristics: (1) high IPC techniques ranging from microarchitecture to code generation; (2) "microarchitecture turbo" techniques that marshal chip resources and system memory bandwidth to accelerate sequential or single-threaded programs; and (3) techniques to support efficient compiler code generation. Success in this area promises to provide significant performance improvements that continue the trends characterized by Moore's Law.

II. PROGRAM DESCRIPTION

Advancing process development in order to sustain the economies of scale of the semiconductor business is becoming very costly; for each new process generation, more than two generations of architecture designs are being introduced to maintain the compound annual growth rate (CAGR) in performance anticipated by the marketplace. Hence, this program seeks to support the architecture and design community in pursuing transformative research to address this challenge.

With the stalling of clock frequency growth, there is added need for architecture and design innovations that drive performance growth. Recent success in techniques that exploit TLP and DLP has prompted renewed attention on single-thread performance. Improving IPC with stagnating clock frequency requires improvements in ILP.

Improving ILP still faces fundamentally difficult constraints, e.g., branch misprediction and cache misses. Overcoming these constraints, while difficult, promises to bring substantial increases in IPC. While these constraints have remained for a very long time, there are presently opportunities for significant advances. Prior to multicore designs, only those microarchitecture mechanisms that could introduce performance improvement commensurate with die area and power investment were selected for implementation for the mainstream microprocessor. Now, multicore systems with more than a dozen cores are quite common. When the system runs a single threaded program (or runs a critical section in a multi-threaded program), die area and power investment from the entire chip and all of the bandwidth from system memory are available for boosting single-thread performance. An example of such a strategy is boosting voltage and frequency for the core that is active, redirecting a large fraction of the system power budget and bandwidth to that core.

This program will support microarchitecture research targeting improvements in IPC, with a particular emphasis on techniques beyond simplistic scaling of the existing microarchitecture structures. Success in this area promises to provide significant performance improvements to continue the performance cadence promised by and commensurate with the transistor density that Moore's Law characterizes. Of particular interest are:

This program seeks the following high level research objectives:

- **High IPC techniques** spanning from microarchitecture to code generation innovations;
- **"Microarchitecture turbo"** techniques that marshal chip resources and system memory bandwidth to accelerate sequential or single-threaded programs; and
- Techniques to support **efficient compiler code generation**.

In order to address the previously stated objectives, FoMR seeks research proposals that explore one or more of the following areas (note that this list is not exhaustive):

- **Microarchitecture and code generation techniques** to boost branch prediction accuracy puts an upper bound on the ILP achievable by programs. There are still branches that are very hard to predict, and these offer an opportunity to push the upper bound higher. Similar situations apply to memory disambiguation and cache management: on average, these are working well, but some behavior remains hard to predict. Cache miss ratios are low for many programs but are high for some other programs; they also place an upper bound on the achievable ILP.
- **Instruction scheduling and organization of execution resources** to enable efficient, very-large instruction window processors. Improving ILP requires the instruction window to be enlarged substantially. A very-large instruction window creates challenges in complexity and lengthens critical path delay.
- **Next-generation prefetchers** with vastly higher coverage than possible today, especially in light of emerging memory technologies. Emerging memory technologies, while non-volatile, have read latencies that are often higher than dynamic random-access memory (DRAM), and write latencies that are much higher than DRAM. In addition, they often have write endurance problems. Techniques to redesign prefetching so that coverage can be increased substantially are desired. Techniques to redesign prefetching so that it works well with emerging memory technologies are desired as well.
- **Cache management** techniques that work efficiently across multiple levels of cache hierarchy comprising heterogeneous memories [e.g., static random-access memory (SRAM), high bandwidth memory (HBM), or traditional DRAM]. These may include cache allocation, replacement, bypassing, prefetching, etc., in the context of heterogeneous memories
- **Machine learning and data analytics-based approach** to improving microarchitecture design and runtime tuning. Machine learning and data analytics provide new tools for improved ability to understand and optimize microarchitecture and program behavior. These tools may be utilized for runtime tuning of microarchitecture parameters so that they can be adapted to execute programs more efficiently.
- **Utilization of new microarchitecture building blocks**, such as reconfigurable logic to boost IPC. As fine-grain reconfigurable fabric [e.g., classic field-programmable gate arrays (FPGA)] and coarse-grain reconfigurable arrays (CGRA) become integrated into microprocessors, they have potential to become the foundational implementation building block akin to

SRAM and the register file to enable novel microarchitecture structures for general-purpose microprocessors. For example, they can be used to construct workload-specific branch predictors or memory prefetchers that comprehend salient patterns in control flow behavior or memory access behavior unique to workload execution, in particular, cloud computing. Enabling such deployment-aware, workload-specific predictors that can be programmed and updated in-the-field is akin to a traditional microcode update in the virtualized environment.

- **Microarchitecture support for efficient compiler code generation** beyond trace generation and traditional performance counter profiling. There is a need for microarchitectures to provide higher-fidelity feedback to the compiler, so that the compiler can generate more efficient code, either for recompilation purposes or for just-in-time optimizations.
- **Criticality-oriented design and techniques.** Critical path delay limits ILP and the overall performance of computer systems. Techniques that reduce the critical path delay, and at the same time exploit slacks on non-critical paths in order to boost ILP, are desired.
- **Microprocessor and process co-optimization.** Microprocessors and processes are often designed separately. However, there are opportunities for co-design, which in turn would enhance optimization, and these should be exploited when possible and practical to improve ILP.

FoMR further encourages proposals to pursue open source approaches that will facilitate reproducibility and reuse of research results by the broader microarchitecture research community. Proposing teams are encouraged to outline their plans in this regard as part of the Project Description and Data Management Plan sections of their proposals.

III. AWARD INFORMATION

Anticipated Type of Award: Standard Grant or Continuing Grant or Intel Agreement (i.e., Contract, Grant or Gift)

Estimated Number of Awards: Approximately 5 awards are anticipated, each up to $500,000 and up to 3 years in duration, subject to the availability of funds and quality of proposals received.

Anticipated Funding Amount: $2,500,000, subject to the availability of funds and quality of proposals received.

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

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

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

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

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

This limit on the number of proposals per PI, co-PI, or senior personnel applies only to this NSF/Intel Partnership on Foundational Microarchitecture Research (FoMR) program solicitation.

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

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

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

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

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

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

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

Proposal Title:

A proposal title must begin with the acronym **FoMR**, followed by a colon, and then the title of the proposed project. If you submit a proposal as part of a set of collaborative proposals, the title of the proposal should begin with **FoMR**, followed by a colon, then "**Collaborative Research**", followed by a colon, and then the title of the proposed project. For example, if you are submitting a collaborative set of proposals, the title of each proposal would be **FoMR: Collaborative Research: Title.**

Project Description:

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

Supplementary Documents:

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

1. *A 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. *Collaboration Plans (if applicable; note: in collaborative proposals, the lead institution should provide this information for all participants)*:

   Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, **all FoMR projects that include more than one investigator must include a Collaboration Plan of up to 2 pages**. The length and degree of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Where appropriate, the Collaboration Plan might include: 1) the specific roles of the project participants in all organizations involved; 2) information on how the project will be managed across all the investigators, institutions, and/or disciplines; 3) identification of the specific coordination mechanisms that will enable cross-investigator, cross-institution, and/or cross-discipline scientific integration (e.g., yearly workshops, graduate student exchanges, project meetings at conferences, use of videoconferences, software repositories, etc.); and 4) specific references to the budget line items that support collaboration and coordination mechanisms. **If a FoMR project with more than one investigator does not include a Collaboration Plan of up to 2 pages, that proposal will be returned without review.**

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

   Each proposal that requests funding to support postdoctoral researchers must include, as a supplementary document, a description of the mentoring activities that will be provided for such individuals. In no more than one page, the mentoring plan

must describe the mentoring that will be provided to all postdoctoral researchers supported by the project, irrespective of whether they reside at the submitting organization, any subawardee organization, or at any organization participating in a simultaneously submitted collaborative project. Please be advised that if required, FastLane will not permit submission of a proposal that is missing a Postdoctoral Researcher Mentoring Plan. See Chapter II.C.2.j of the *Proposal and Awards Policies and Procedures Guide* (PAPPG) for further information about the implementation of this requirement.

4. *Data Management Plan (required):*

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

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

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

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

5. *Documentation of collaborative arrangements of significance to the proposal through Letters of Collaboration:*

   There are two types of collaboration, one involving individuals/organizations that are included in the budget, and the other involving individuals/organizations that are not included in the budget. Collaborations that are included in the budget should be described in the Project Description. Any substantial collaboration with individuals/organizations not included in the budget should be described in the Facilities, Equipment and Other Resources section of the proposal (see PAPPG Chapter II.C.2.i). In either case, whether or not the collaborator is included in the budget, **a letter of collaboration from each named participating organization *other than the submitting lead, non-lead, and/or subawardee institutions* should be provided at the time of submission of the proposal. Such letters should explicitly state the nature of the collaboration, appear on the organization's letterhead and be signed by the appropriate organizational representative. These letters must not otherwise deviate from the restrictions and requirements set forth in the PAPPG, Chapter II.C.2.j.**

   Please note that letters of support may not be submitted. Such letters do not document collaborative arrangements of significance to the project, but primarily convey a sense of enthusiasm for the project and/or highlight the qualifications of the PI or co-PI. **Reviewers will be instructed not to consider these letters of support in reviewing the merits of the proposal.**

   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. Grants.gov Users: The COA information must be provided through use of the COA template and uploaded as a PDF attachment.

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

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Other Budgetary Limitations:

It is expected that PIs, co-PIs, and students of funded projects will participate in annual PI meetings. All such expenses are to be included in project budgets for the duration of the project. Intel will support travel and the expenses associated with the annual meetings for Intel participants. Intel will support all travel-related expenses for PIs, co-PIs, and students as well as meeting expenses for any additional meetings/retreats that Intel requests and organizes in association with this solicitation.

C. Due Dates

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

  November 28, 2018

D. FastLane / Grants.gov Requirements

For Proposals Submitted Via FastLane:

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

6188 or e-mail fastlane@nsf.gov. The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

For Proposals Submitted Via Grants.gov:

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

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

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

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

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

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

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

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

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

A. Merit Review Principles and Criteria

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

1. Merit Review Principles

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

in basic research and education, the following three principles apply:

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

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

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

2. Merit Review Criteria

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

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

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

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

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

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

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

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

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 Internal Review by Intel Corporation.

Intel and NSF will each conduct separate proposal reviews. Upon conclusion of the separate reviews, award recommendations will be coordinated jointly by NSF and Intel.

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

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

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

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

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

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

B. Award Conditions

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

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

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

Special Award Conditions:

Each awarded project will be jointly funded by the NSF and Intel 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. **Site visits, meetings, and annual retreats**

   Intel and NSF will organize annual retreats for awardees which will bring together the academic community involved in the FoMR program, along with NSF and Intel personnel who have interest in the programs. Intel and NSF will work with academic leadership to organize these events. They will involve reviews of the research underway in each project along with presentations from NSF and 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**

   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 Foundational Microarchitecture Research under Award Title and No. [Recipient enters project title and awards number(s)]."

   All projects agree to distribute all source code that has been authored while working on an NSF/Intel award under a 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 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, royalty-free, sub-licensable license to all intellectual property rights in any inventions or works of authorship resulting from research conducted under the joint award.

3. **Intel participation in research**

   Intel may separately fund its own personnel to directly participate in NSF/Intel Partnership research, 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 tech 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 in the Project Management Plan for each NSF/Intel Partnership award. Further, Intel may designate one of its more senior, separately funded researchers to work alongside NSF/Intel Partnership academic lead PIs. The Intel FoMR Program Director and the lead Intel researcher may work with the academic PI of each project to collaboratively oversee the project, manage Intel's participation in each project, champion considerations related to innovation – the translation of discoveries into industry impact – and manage the center on a day-by-day basis. 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.

4. **Program management**

   The Intel FoMR Program Director overseeing funded projects may become a member of the Project Management Team for the Intel award. Intel will conduct annual retreats and 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 quarterly or more frequent 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.

5. **Funding Support and Budget Revisions**

   Individual awards selected for joint funding by NSF and Intel will be funded through separate NSF and Intel funding instruments. For each such project, NSF support will be provided via an NSF grant and Intel support will be provided via an Intel agreement (i.e., Contract, Grant or Gift). Either organization may supplement a project without requiring the other party to provide any additional funds.

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

C. Reporting Requirements

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

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

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

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

In addition, Intel may require semi-annual reports to monitor project progress.

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:

- Yuanyuan Yang, Program Director, CCF, telephone: (703) 292-8910, email: yyang@nsf.gov
- Matt Haycock, Center Executive Sponsor, Vice President, Intel Labs, telephone: (503) 712-2872, email: matthew.haycock@intel.com
- Hong Wang, Center Managing Sponsor, Intel Fellow, Intel Labs, telephone: (408) 653-7075, email: hong.wang@intel.com
- Jeff Parkhurst, Center Program Director, Intel Labs, telephone: (916) 356-2508, email: jeff.parkhurst@intel.com

For questions related to the use of FastLane, contact:

- FastLane Help Desk, telephone: 1-800-673-6188; e-mail: fastlane@nsf.gov.

For questions relating to Grants.gov contact:

- Grants.gov Contact Center: If the Authorized Organizational Representatives (AOR) has not received a confirmation message from Grants.gov within 48 hours of submission of application, please contact via telephone: 1-800-518-4726; e-mail: support@grants.gov.

IX. OTHER INFORMATION

The NSF website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this website by potential proposers is strongly encouraged. In addition, "NSF Update" is an information-delivery system designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF Grants Conferences. Subscribers are informed through e-mail or the user's Web browser each time new publications are issued that match their identified interests. "NSF Update" also is available on NSF's website.

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding opportunities may be accessed via this mechanism. Further information on Grants.gov may be obtained at http://www.grants.gov.

ABOUT THE NATIONAL SCIENCE FOUNDATION

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

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

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

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

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

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

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

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at https://www.nsf.gov

- **Location:** 2415 Eisenhower Avenue, Alexandria, VA 22314
- **For General Information** (NSF Information Center)**:** (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**

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

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

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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

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

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Reports Clearance Officer
Office of the General Counsel
National Science Foundation
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