

# Computing and Communication Foundations (CCF): Core Programs

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## PROGRAM SOLICITATION NSF 18-568

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### REPLACES DOCUMENT(S): NSF 17-571

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National Science Foundation

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

#### Submission Window Date(s) (due by 5 p.m. submitter's local time):

September 24, 2018 - October 02, 2018

MEDIUM projects

November 01, 2018 - November 15, 2018

SMALL projects

September 09, 2019 - September 16, 2019

MEDIUM projects

October 31, 2019 - November 14, 2019

SMALL projects

## IMPORTANT INFORMATION AND REVISION NOTES

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This is a revision of [NSF 17-571](#), the solicitation for the CISE/CCF Core Programs. Significant changes have been made to the program description. The revisions include:

- A new CCF Core Program, Foundations of Emerging Technologies (FET), has been added to the existing set of CCF Core Programs.
- The requirement of a Collaboration Plan for all proposals with more than one investigator for MEDIUM proposals.
- The Office of Advanced Cyberinfrastructure (OAC) is now part of the coordinated solicitation, along with CCF (this solicitation), Computer and Network Systems (CNS), and Information and Intelligent Systems (IIS).
- Broadening Participation in Computing plans are strongly encouraged for Medium proposals, and approved plans are required before award.
- Proposers are asked not to request start dates between July 2 and September 30 of a given year.
- Eligibility requirements for PIs, co-PIs, and senior personnel are clarified.
- The placement of keywords in the Project Summary is clarified.
- Evaluation plans are encouraged.
- The section on Embedded REU Supplements has been removed. Requests for REU supplements may still be submitted in accordance with applicable *NSF Proposal & Award Policies & Procedures Guide (PAPPG)* and CISE guidance.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide (PAPPG)* ([NSF 19-1](#)), which is effective for proposals submitted, or due, on or after February 25, 2019.

## SUMMARY OF PROGRAM REQUIREMENTS

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### General Information

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Program Title:

Computing and Communication Foundations (CCF): Core Programs

**Synopsis of Program:**

CISE's Division of Computing and Communication Foundations (CCF) supports research and education projects that develop new knowledge in four core programs:

- The Algorithmic Foundations (AF) program;
- The Communications and Information Foundations (CIF) program;
- The Foundations of Emerging Technologies (FET) program; and
- The Software and Hardware Foundations (SHF) program.

Proposers are invited to submit proposals in two project classes, which are defined as follows:

- Small Projects - up to \$500,000 total budget with durations up to three years; and
- Medium Projects - \$500,001 to \$1,200,000 total budget with durations up to four years.

A more complete description of the two project classes can be found in section II. *Program Description* of this document.

*CCF proposals must be in the Small or Medium classes only.*

**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, Point of Contact, Software and Hardware Foundations (SHF), telephone: (703) 292-8910, email: [abanerje@nsf.gov](mailto:abanerje@nsf.gov)
- Mitra Basu, Point of Contact, Foundations of Emerging Technologies (FET), telephone: (703) 292-8910, email: [mbasu@nsf.gov](mailto:mbasu@nsf.gov)
- Tracy Kimbrel, Point of Contact, Algorithmic Foundations (AF), telephone: (703) 292-8910, email: [tkimbrel@nsf.gov](mailto:tkimbrel@nsf.gov)
- Dmitry Maslov, Point of Contact, Foundations of Emerging Technologies (FET), telephone: (703) 292-8910, email: [dmaslov@nsf.gov](mailto:dmaslov@nsf.gov)
- Phillip Regalia, Point of Contact, Communications and Information Foundations (CIF), telephone: (703) 292-8910, email: [pregalia@nsf.gov](mailto:pregalia@nsf.gov)

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

- 47.070 --- Computer and Information Science and Engineering

**Award Information**

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**Anticipated Type of Award:** Standard Grant or Continuing Grant

**Estimated Number of Awards:** 170 to 250

**Anticipated Funding Amount:** \$100,000,000

Dependent on the availability of funds.

**Eligibility Information**

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**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:**

As of the submission deadline, PIs, co-PIs, or other senior project personnel must hold primary, full-time, paid appointments in research or teaching positions at US-based campuses/offices of organizations 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, or overseas branch campuses of US IHEs are not eligible, even if they also have an appointment at a US campus.

#### Limit on Number of Proposals per Organization:

There are no restrictions or limits.

#### Limit on Number of Proposals per PI or Co-PI: 2

In any contiguous September through November period, an individual may participate as PI, co-PI or Senior Personnel in **no more than two** proposals across all size classes submitted in response to the *coordinated solicitations* (where *coordinated solicitations* are defined to include the *Computer and Network Systems (CNS): Core Programs*, *Computing and Communication Foundations (CCF): Core Programs*, *Information and Intelligent Systems (IIS): Core Programs*, and the *Office of Advanced Cyberinfrastructure (OAC): Core Programs* solicitations). For example, between September 2018 and November 2018, an individual may participate as PI, co-PI or Senior Personnel in one proposal submitted to a core program in CCF and in a second proposal submitted to a core program in CNS, or an individual may participate as PI, co-PI or Senior Personnel in two proposals submitted to an IIS core program, etc.

**These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently.** In the event that an individual exceeds this limit, proposals received within the limit will be accepted based on earliest date and time of proposal submission (i.e., the first two proposals received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

The limit on the number of proposals per PI, co-PI or Senior Personnel applies only to the *coordinated solicitations*.

## Proposal Preparation and Submission Instructions

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### 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](https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg).
  - Full Proposals submitted via Research.gov: *NSF Proposal and Award Policies and Procedures Guide (PAPPG)* guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at: [https://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=pappg](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](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

- **Submission Window Date(s)** (due by 5 p.m. submitter's local time):
  - September 24, 2018 - October 02, 2018
    - MEDIUM projects
  - November 01, 2018 - November 15, 2018
    - SMALL projects
  - September 09, 2019 - September 16, 2019
    - MEDIUM projects
  - October 31, 2019 - November 14, 2019
    - SMALL projects

## Proposal Review Information Criteria

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### Merit Review Criteria:

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

## Award Administration Information

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### Award Conditions:

Standard NSF award conditions apply.

### Reporting Requirements:

Standard NSF reporting requirements apply.

## TABLE OF CONTENTS

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### Summary of Program Requirements

- I. Introduction
- II. Program Description
- III. Award Information
- IV. Eligibility Information
- V. Proposal Preparation and Submission Instructions
  - A. Proposal Preparation Instructions
  - B. Budgetary Information
  - C. Due Dates
  - D. [FastLane/Research.gov/Grants.gov Requirements](#)
- VI. NSF Proposal Processing and Review Procedures
  - A. Merit Review Principles and Criteria
  - B. Review and Selection Process
- VII. Award Administration Information
  - A. Notification of the Award
  - B. Award Conditions
  - C. Reporting Requirements
- VIII. Agency Contacts
- IX. Other Information

## I. INTRODUCTION

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The Division of Computing and Communication Foundations (CCF) supports transformative research and education projects that explore the foundations of computing and communication. The Division seeks advances in algorithm design and analysis, computing and communication theory, computing and communication models based on novel emerging technologies, and the architecture and design of computers and software. CCF-supported projects also integrate research and education activities to prepare future generations of computer science and engineering workers.

## II. PROGRAM DESCRIPTION

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CCF supports four core programs as described below - Algorithmic Foundations (AF), Communications and Information Foundations (CIF), Foundations of Emerging Technologies (FET) and Software and Hardware Foundations (SHF).

## **Algorithmic Foundations (AF)**

The Algorithmic Foundations (AF) program supports potentially transformative projects in the theory of algorithms. Projects should be characterized by algorithmic innovation accompanied by rigorous analysis. Of interest is research on algorithms for problems that are central to computer science and engineering, as well as new techniques for the rigorous analysis of algorithms and computational complexity. AF supports theoretical research that bounds the intrinsic difficulty of problems to determine measures of complexity in formal models of computation, classical or new. The goal is to understand the fundamental limits of resource-bounded computation and to obtain efficient algorithms operating within those limits. Research on resources other than the traditional time and space measures, such as communication and energy, is also encouraged, as is research on tradeoffs between resource use and solution quality, such as running time vs. approximation error. In addition to the traditional sequential computing paradigm, AF supports research on the design and analysis of novel algorithms in parallel and distributed models, as well as computational models and algorithms that capture essential aspects of computing over massive data sets.

New techniques for the design and analysis of algorithms and analysis of problem complexity in areas such as optimization, cryptography, computational geometry, game theory, social networks, and numeric, symbolic, and algebraic computing are within the scope of this program. The program also supports research in algorithms needed in applied areas of research. Algorithmic research on problems arising from areas including databases, machine learning, data mining, robotics, computer vision, networks, communications, operating systems, computer memory models, programming languages, compilers, and machine abstractions is supported. While relevance to application areas is important and collaboration with researchers in these areas is encouraged, research funded by this program must advance the theoretical study of algorithms. When accompanying rigorous analysis of computational resource requirements and/or algorithmic performance measures, implementation efforts and empirical evaluation are considered strong broader impacts. In these cases, letters of collaboration from applied researchers are encouraged.

Emerging topics such as quantum computing and biological models of computation are now addressed in the Foundations of Emerging Technologies (FET) program. However, projects in these areas focused on foundational issues of algorithms and complexity in these topics, as described above, can also be considered by the AF program.

Research that incorporates significant activity in both algorithmic theory and practice is generally supported through other, cross-cutting programs. Some examples are Critical Techniques, Technologies, and Methodologies for Advancing Foundations and Applications of Big Data Sciences & Engineering (BIGDATA); Integrative Strategies for Understanding Neural and Cognitive Systems (NSF-NCS); National Robotics Initiative 2.0: Ubiquitous Collaborative Robots (NRI-2.0); Secure and Trustworthy Cyberspace (SaTC); and Smart and Connected Health: Connecting Data, People, and Systems (SCH).

## **Communications and Information Foundations (CIF)**

The Communications and Information Foundations (CIF) program supports potentially transformative research that addresses the theoretical underpinnings of information acquisition, transmission, and processing in communications and information processing systems. As a result, CIF projects strengthen the intellectual foundations of communications, information theory, signal processing, and statistical learning in a variety of network types such as wireless and multimedia networks, sensor networks, social networks, and biological and quantum networks. Research outcomes are expected to lead to more secure and reliable communications and advanced mathematical capabilities that are applicable throughout science and engineering.

The CIF program supports basic research in communication theory, information theory, and signal processing. Included in the CIF program is the reliable transmission of information in the presence of a variety of resource constraints (e.g., energy, bandwidth, computation, time, and privacy) and channel impairments (e.g., noise, multipath, interference, and eavesdroppers). CIF likewise has a strong interest in the role of signal processing, coding, and information theory in distributed processing systems handling massive amounts of data and impacting the control, operation and robustness of real-time systems and networks, including human-in-the-loop modeling, processing, and learning.

The CIF program also supports foundational research in networking including network information theory and cross-layer research at the lower layers. The CIF program in networking emphasizes research in which the physical-layer attributes play an important role in understanding overall network design and performance. This includes cross-layer approaches that consider the impact of physical-layer characteristics on higher network layers. Examples include secure communication; sensor networks with applications including environmental monitoring, crowd-sourcing, and smart grids; and other application scenarios that feature massive data aggregation from distributed sensing, such as the Internet of Things.

In addition to the contemporary signal processing topics that have enabled the information revolution, there is growing interest within the CIF program in new paradigms that enlarge the scope of signal processing and information theory such as advances in statistical learning and inference, signal processing on graphs, distributed processing for multi-terminal communication problems, information-theoretic security, the all-pervasive role of geometric methods in signal processing and machine learning, new mathematical frameworks for addressing new problems, communication-theoretic challenges in terahertz and millimeter-wave frequencies, and machine learning for network optimization. Research that will develop efficient, power-aware and hardware-friendly algorithms and research on signal/information processing algorithms for the new network science of distributed, decentralized, and cooperative algorithms is encouraged. Also within scope is the derivation of efficient algorithms and fundamental limits for extracting information from massive and possibly corrupted data sets, including compressive sampling/sensing and active learning, and exploring new application domains.

The CIF program is particularly interested in the study of signal/information processing in complex systems, as signal processing and information theory may be viewed more broadly and holistically by other areas, such as in machine learning and data science. Some examples of complex systems and applications include monitoring the Nation's critical infrastructures, signal processing and information theory in biological systems, and information flow in socio-technical networks. While advances in these areas have the potential for broad societal impact, the study of these and other emerging application domains is expected to lead to new insights in the underlying theory by posing new constraints and challenges as well as reexamining old questions and assumptions, e.g., new mathematical approaches to deep learning.

Emerging topics such as quantum computing and biological models of computation are now addressed in the Foundations of Emerging Technologies (FET) program. However, projects in these areas focused on foundational issues of information acquisition, transmission, and processing, as described above, can also be considered by the CIF program.

## Foundations of Emerging Technologies (FET)

Foundations of Emerging Technologies (FET) is a new program within CCF that aims to enable radical innovations across all areas traditionally supported by CCF, including the theory, algorithms, software, hardware, and architecture of computing and communication systems, through research at the intersection of computing and biological systems, nanoscale science and engineering, quantum information science, and other nascent, yet promising, areas. Interdisciplinary collaborations between computer and information scientists as well as those in various other fields such as biology, chemistry, engineering, mathematics and physics are highly encouraged, with the aim of pursuing foundational breakthroughs in computer and information science.

The FET program seeks potentially transformative projects in the research areas elaborated below:

*Biological Systems Science and Engineering* explores opportunities at the intersection of biology and computer science, with a specific focus on activities that advance our understanding of computing and communication processes in biological systems in order to recreate or use them as models for, or demonstrations of, innovative computing and communication systems. Topics of interest include, but are not limited to: understanding the complexity of biological systems via algorithmic, mathematical, and/or stochastic modeling techniques for simulation and analysis of biological systems and biochemical networks at multiple scales; and using the computing power of bio-molecules in designing systems that complement and extend the capability of silicon-based computing systems.

*Quantum Information Science* explores opportunities in quantum computing, quantum communication, and other quantum-based and related approaches for processing, communicating, and using information. Topics of interest include, but are not limited to: development of a broad and general collection of quantum algorithms (including both algorithm theory and algorithm design); study of quantum programming languages, quantum architectures, and quantum circuits; simulation of quantum algorithms and systems; design of quantum computers and systems; benchmarking, programming, optimizing, and testing quantum computer systems (through, e.g., a cloud service or in the lab); development of both theoretical and practical approaches to fault tolerance; demonstration of scalable quantum computations (paving the road to quantum supremacy, demonstrating quantum supremacy, or post-supremacy); and studies of the use of quantum information in communication and networking, as well as more broadly.

*Nanotechnology for Computing and Communication* explores opportunities using nanotechnology for (1) disruptive system architectures, circuit micro-architectures, and attendant device and interconnect technology aimed at achieving the highest level of computational energy efficiency for general-purpose computing systems; and (2) architectures and circuits associated with revolutionary device concepts that will greatly extend the practical engineering limits of energy-efficient computation. A cross-layer approach for simultaneous development of hardware design starting at the lowest level of the computing stack and extending to higher levels is encouraged. At the circuits level, alternative state vectors (i.e., non-charge-based devices such as those relying on spin, magnetism, and phase state of materials) possibly involving non-silicon (e.g., carbon nanotubes, two-dimensional materials, optics, etc.) technologies are entertained.

*Neuromorphic Computing and Architecture* explores opportunities in hardware architectures inspired by the human brain, particularly those enabling synergistic use of materials and device technologies, along with their efficient implementations. Examples include traditional neural network architectures, their recurrent and deep learning versions, other more modern variants (e.g., spiking models), and other computing models of the human brain such as hyper-dimensional computing. Novel algorithms and hardware experimentation of both model-based or model-free machine learning algorithms, e.g., those inspired by information theory and/or statistical mechanics, are entertained as well.

The FET program supports research in information processing and computing with probabilistic devices. Such research should address the future where devices will be plagued by quantum effects, fragility, extreme variability, and low signal-to-noise ratio, thus exhibiting more probabilistic nature of operation than the deterministic systems that exist today.

## Software and Hardware Foundations (SHF)

The Software and Hardware Foundations (SHF) program supports potentially transformative research in the design, verification, operation, utilization, and evaluation of computer hardware and software through novel approaches, robust theories, high-leverage tools, and lasting principles. Such advances may offer formal methods, languages, logic, novel software and/or hardware artifacts, or algorithms to enable new or enhanced functionality, verification, usability, and scale.

The SHF program supports all aspects of the science and engineering of software, seeking transformative ideas that reformulate the relationships between requirements, design and evolution of software, and software-intensive systems. SHF supports research projects focusing on program analysis and synthesis, compositionality, verifiability and adaptability of software, as well as research on software analysis and testing techniques for all stages of the software life cycle. SHF also seeks research to increase the automation of software engineering capabilities to attain significant advances in quality and sustainability of software, which may require new representations and processes. Empirical research that increases understanding of software and software creation is also in scope.

The SHF program supports fundamental research on formal and semi-formal methods for the specification, development, and verification of software and hardware systems. This includes, but is not limited to, abstraction, compositional, refinement-based, and probabilistic methods for the modeling and validation of systems involving discrete and continuous behavior. The program seeks proposals that enhance the applicability, usability, and efficiency of techniques such as abstract interpretation, model checking, theorem proving, automated decision procedures, and constraint solving. Research topics involving the semantics, logics, verification, and analysis of concurrent systems are in scope. SHF supports foundations, algorithms, and tools for software and hardware synthesis.

The SHF program supports the entire range of programming languages research, from foundations to design to implementation. Fundamental research in both science and engineering of programming languages is highly encouraged. Topics of interest include, but are not limited to, language semantics and type theory, design and implementation of advanced languages and language features, compilers and runtime systems for advanced languages, program analysis and optimization, design and implementation of domain-specific languages, and implementation issues related to locality, synchronization, and communication. Research in programming languages and models that go beyond mainstream practice, such as concurrent, functional, logic programming and probabilistic languages, is particularly encouraged. Foundational research that exposes novel synergies between programming languages and other areas of computing, such as distributed systems, is also encouraged.

The SHF program supports foundational research in computer architecture and computer hardware and systems design, including, but not limited to, performance, energy efficiency, reliability, scalability, concurrency, and heterogeneity. The program supports fundamental

and transformative research in processors, interconnects, memory, and storage architectures. The program seeks research that takes holistic and cross-layer approaches to fully harness the promises and address the challenges of new and emerging substrate technologies and materials, and that considers emerging trends in application environments including computation-intensive, data-intensive, and I/O-intensive applications.

The SHF program supports foundational research in high-performance computing that is aware of, driven by, and inspired by applications, as well as heterogeneity-aware and architecture-aware. SHF does not support research in domain applications. SHF seeks novel research on enabling technologies and tools to balance and optimize performance goals including scalability, power, productivity, repeatability, reliability, and validity.

The SHF program supports fundamental research in all topics in design automation, including but not limited to, logical, physical, behavioral, and high-level synthesis methods; interplay between synthesis and verification; design methodologies for scalable, low-power and energy-efficient circuits; and physical design in silicon technologies. Also of interest is pre- and post-silicon validation, possibly by using a blend of techniques from testing and verification. SHF seeks research in emerging technologies, including optical interconnects, optical computing, bio-computing, bio-inspired devices, nanotubes and nanophotonics, which have the potential to take computation beyond Moore's Law. Implementation of novel non-silicon CMOS emerging devices in non-von Neumann architectures, e.g., oscillator arrays, etc., is an area of interest to the SHF program.

Emerging topics such as design involving non-silicon, non-von Neumann architectures, including neuromorphic, or more generally brain inspired architectures, are now addressed in the Foundations of Emerging Technologies (FET) program. However, projects within these topics focused on the design automation for micro- and nano-systems or computer architecture can also be considered by the SHF program.

Proposals on parallelism and scalability of parallel computing are supported through the Scalable Parallelism in the Extreme (SPX) program. Proposals that address hardware and/or software security may be in scope for the Secure and Trustworthy Cyberspace (SaTC) program. Proposals that focus on computer system issues, solutions, implementations, and verification at the systems level may also wish to consider the Computer Networks and Systems (CNS) Core program.

## PROJECT CLASSES

Proposals submitted to this solicitation must be consistent with one of two project classes defined below. Proposals will be considered for funding within their project classes.

- **SMALL Projects**

**Small Projects, with total budgets up to \$500,000 for durations of up to three years**, are well suited to one or two investigators (PI and one co-PI or other Senior Personnel) and at least one student and/or postdoc. A collaboration plan (up to 2 pages) **may** be provided under Supplementary Documentation. Please see Proposal Preparation Instructions Section V.A for additional submission guidelines.

- **MEDIUM Projects**

**Medium Projects, with total budgets ranging from \$500,001 to \$1,200,000 for durations up to four years**, are well suited to one or more investigators (PI, co-PI and/or other Senior Personnel) and several students and/or postdocs. Medium 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. Rationale must be provided to explain why a budget of this size is required to carry out the proposed work. Since the success of collaborative research efforts are known to depend on thoughtful coordination mechanisms that regularly bring together the various participants of the project, **a Collaboration Plan is required for any Medium project with more than one investigator**, even when the investigators are affiliated with the same institution. Up to 2 pages are allowed for Collaboration Plans and they must be submitted as a document under Supplementary Documentation. The length of and level of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Collaboration plans and proposed budgets should demonstrate that key personnel, and especially lead PIs, have allocated adequate time for both their individual technical contributions and the leadership of collaborative activities necessary to realize the synergistic effects of larger-scale research. **If a Medium project with more than one investigator does not include a Collaboration Plan, that proposal will be returned without review.** Please see *Proposal Preparation Instructions* Section V.A for additional submission guidelines.

- **LARGE Projects**

**Large proposals may not be submitted to the CCF Core programs. Large proposals submitted simultaneously to any other CISE core program and a CCF core program will be returned without review (RWR).**

## EVALUATION PLANS

PIs should include a plan to evaluate the approaches developed as part of the Project Description. Evaluation methods will depend on the research area; examples include results from development of theories, applications of techniques to specific domains, efficacy studies, scalability on local or global scales, generalization, quantifiable usability, robustness, reliability in benign or hostile environments, compatibility with existing environments, performance measures on benchmark datasets, and other such activities. The plan should be appropriate for the size and scope of the project.

## BROADENING PARTICIPATION IN COMPUTING

CISE has long been committed to Broadening Participation in Computing (BPC). The under-representation of many groups—including women, African Americans, Hispanics, American Indians, Alaska Natives, Native Hawaiians, Native Pacific Islanders, and persons with disabilities—in computing deprives large segments of the population of the opportunity to be creators of technology and not only consumers. Ending underrepresentation will require a range of measures, including institutional programs and activities as well as culture change across colleges, departments, classes, and research groups.

With this solicitation, CISE is expanding a pilot effort started last year encouraging the research community to engage in meaningful

BPC activities. This new activity builds on many of the programs, research, and resources created in CISE's long history of support for BPC, and it aligns with the recommendations of the Strategic Plan for Broadening Participation produced by the CISE Advisory Committee in 2011. Specifically:

- Each Medium project must, by the time of award, have in place an approved BPC plan. In this ongoing pilot phase, CISE will work with each PI team following merit review and prior to making an award to ensure that plans are meaningful and include concrete metrics for success. CISE will also provide opportunities for PIs to share BPC experiences and innovations through program PI meetings. PIs of Medium proposals are therefore strongly encouraged to consider this eventual requirement as they develop their proposals, and to include one- to three-page descriptions of their planned BPC activities under Supplementary Documents in their submissions. Feedback will be provided on such plans.
- PIs submitting to the Small size class should note that CISE intends to conduct an evaluation of the effectiveness of the above approach and determine appropriate next steps, including potential further expansion of this effort in future years. PIs of Small proposals are therefore strongly encouraged to include plans, or begin preparing to include plans, for broadening participation activities in their proposals.

More information, including examples of BPC activities and metrics, can be found at: <https://www.nsf.gov/cise/bpc/>.

#### **PROPOSALS FOR CONSIDERATION BY MULTIPLE CISE PROGRAMS**

Proposals that intersect more than one CISE research program are welcome. In such cases, PIs must identify the most relevant programs in the proposal submission process (for information about submission and how to identify such proposals, see *Proposal Preparation Instructions* later in this document). CISE Program Officers will ensure that these proposals are co-reviewed as appropriate.

#### **IMPORTANT PROJECT CHARACTERISTICS**

The submission of far-reaching, creative research and education projects is encouraged. Funds will be used to support potentially transformative research with high-impact potential. In this way, CISE will catalyze exciting new research activities with the potential to make significant advances in the state of the art.

Interdisciplinary, international, and/or academic-industry collaborations that promise to result in major science or engineering advances are welcome. The directorate hopes to attract proposals from faculty at a broad range of academic institutions, including faculty at minority-serving and predominantly undergraduate institutions.

Proposals submitted should demonstrate that rich learning experiences will be provided for a diverse population of students and may propose the development of innovative curricula or educational materials that advance literacy about and expertise in areas supported by CISE.

Scientific progress often results by considering a special case of a general problem. If the proposed research falls into this category, PIs can help the reviewers and NSF staff better understand the intellectual merit and/or broader impacts of the proposal by discussing to what extent the findings are likely to generalize.

In the interest of completeness and transparency, PIs are strongly encouraged to describe, as part of their Data Management Plans, how they will provide access to well-documented datasets, modeling and/or simulation tools, and codebases to support reproducibility of their methods. For more information, see the Dear Colleague Letter "Encouraging Reproducibility in Computing and Communications Research" available at [https://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=nsf17022](https://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf17022).

#### **START DATES**

In order to avoid overdue reports blocking award actions during the end of a fiscal year, institutions are discouraged from seeking project start dates between July 2 and September 30 of a given year. Awardee institutions may incur allowable pre-award costs within the 90-day period immediately preceding the start date of the grant subject to the conditions specified in the PAPPG; this will allow support for students or other relevant activities to begin over this period.

### **III. AWARD INFORMATION**

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Up to \$100 million each year will support up to 250 awards, depending on the availability of funds.

### **IV. ELIGIBILITY INFORMATION**

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#### **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:

As of the submission deadline, PIs, co-PIs, or other senior project personnel must hold primary, full-time, paid appointments in research or teaching positions at US-based campuses/offices of organizations 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, or overseas branch campuses of US IHEs are not eligible, even if they also have an appointment at a US campus.

#### Limit on Number of Proposals per Organization:

There are no restrictions or limits.

#### Limit on Number of Proposals per PI or Co-PI: 2

In any contiguous September through November period, an individual may participate as PI, co-PI or Senior Personnel in **no more than two** proposals across all size classes submitted in response to the *coordinated solicitations* (where *coordinated solicitations* are defined to include the *Computer and Network Systems (CNS): Core Programs, Computing and Communication Foundations (CCF): Core Programs, Information and Intelligent Systems (IIS): Core Programs*, and the *Office of Advanced Cyberinfrastructure (OAC): Core Programs* solicitations). For example, between September 2018 and November 2018, an individual may participate as PI, co-PI or Senior Personnel in one proposal submitted to a core program in CCF and in a second proposal submitted to a core program in CNS, or an individual may participate as PI, co-PI or Senior Personnel in two proposals submitted to an IIS core program, etc.

**These eligibility constraints will be strictly enforced in order to treat everyone fairly and consistently.** In the event that an individual exceeds this limit, proposals received within the limit will be accepted based on earliest date and time of proposal submission (i.e., the first two proposals received will be accepted and the remainder will be returned without review). **No exceptions will be made.**

The limit on the number of proposals per PI, co-PI or Senior Personnel applies only to the *coordinated solicitations*.

#### Additional Eligibility Info:

Subawards are not permitted to overseas branch campuses/offices of US-based proposing organizations eligible to submit to this solicitation.

## V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

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### A. Proposal Preparation Instructions

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

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: [https://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=pappg](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](mailto:nsfpubs@nsf.gov). Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.
- Full Proposals submitted via Research.gov: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the *NSF Proposal and Award Policies and Procedures Guide* (PAPPG). The complete text of the PAPPG is available electronically on the NSF website at: [https://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=pappg](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](mailto:nsfpubs@nsf.gov). The Prepare New Proposal setup will prompt you for the program solicitation number.
- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the *NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov*. The complete text of the *NSF Grants.gov Application Guide* is available on the Grants.gov website and on the NSF website at: ([https://www.nsf.gov/publications/pub\\_summ.jsp?ods\\_key=grantsgovguide](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](mailto: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.

The following information SUPPLEMENTS (note that it does NOT replace) the guidelines provided in the PAPPG.

**Cover Sheet:** PIs submitting Grant Opportunities for Academic Liaison with Industry (GOALI) proposals should select "GOALI" from the Type of Proposal drop down list in the Proposal Preparation module in FastLane or Grants.gov. Please see Chapter II.E.4 of the PAPPG for additional information about preparing a GOALI proposal:  
[https://www.nsf.gov/pubs/policydocs/pappg17\\_1/pappg\\_2.jsp#IE4](https://www.nsf.gov/pubs/policydocs/pappg17_1/pappg_2.jsp#IE4).

#### Proposal Titles:

Proposal titles must begin with an acronym that indicates the most relevant core program. Select an acronym from the following list:

- Algorithmic Foundations: AF
- Communications and Information Foundations: CIF
- Foundations of Emerging Technologies: FET
- Software and Hardware Foundations: SHF

The acronym should be followed with a colon, then the project class followed by a colon, then the title of your project. For example, if you are submitting a Medium proposal to the Algorithmic Foundations core program, then your title would be **AF: Medium: Title**.

Proposals which cross the CCF core programs, should begin with the acronyms for the programs, then the project class followed by a colon, then the proposal title, e.g., **AF: CIF: Small: Title**.

If a proposal is submitted as part of a set of collaborative proposals, the title of the proposal should begin with the acronym that indicates the most relevant core program followed by a colon, then the project class followed by a colon, then "Collaborative Research" followed by a colon, and the title. For example, if you are submitting a collaborative set of proposals for a Small project to the FET core program, the title of each would be **FET: Small: Collaborative Research: Title**.

Proposals from PIs in institutions that have RUI (Research in Undergraduate Institutions) eligibility should have a proposal title that begins with the acronym that indicates the most relevant core program acronym, followed by a colon then the project class, followed by a colon then "RUI", followed by a colon and then the title, for example, **SHF: Medium: RUI: Title**.

PIs submitting GOALI proposals should have a proposal title that begins with the acronym that indicates the most relevant core program acronym, followed by a colon then the project class, followed by a colon then "GOALI", followed by a colon and then the title, for example, **FET: Small: GOALI: Title**.

Proposals that extend beyond the scope of one CISE core program or area are welcome. Proposals should be submitted in response to the solicitation for the CISE division (CCF, CNS or IIS) that includes the most relevant core program. In such cases, PIs should identify the acronym for the **most relevant** core program or area, followed by any other relevant program acronym(s) separated by colons (for example, **SHF: CNS Core: Medium: Title**). In this case, the proposal would be submitted to the CCF solicitation but would be considered by CCF/SHF and CNS Core program. CISE Program Officers will work with their NSF and CISE colleagues to ensure that these proposals are appropriately reviewed and considered for funding. Please see the coordinated CNS, IIS, and OAC solicitations for information on other CISE core programs and the corresponding acronyms.

**Large proposals may not be submitted to the CCF Core programs. Large proposals submitted simultaneously to any other CISE core program and a CCF core program will be returned without review (RWR).**

#### Project Summary:

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

Please provide between 2 and 6 sets of keywords at the end of the overview in the Project Summary. CISE personnel will use this information in implementing the merit review process. The keywords should describe the main scientific/engineering areas explored in the proposal. Keywords should be prefaced with "Keywords" followed by a colon and each keyword set should be separated by semi-colons. Keywords should be of the type used to describe research in a journal submission, and may include technical areas of expertise necessary to review the proposal. 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; graph theory; qubits; information visualization; privacy**.

#### Project Description:

**Length of Project Description** - Describe the research and education activities to be undertaken in **up to 15 pages for Small and Medium proposals. Proposals that exceed these limits will be returned without review.**

PIs submitting to the Small size class should note that CISE intends to conduct an evaluation of the effectiveness of the BPC pilot approach and determine appropriate next steps, including potential further expansion of this effort in future years. PIs of Small proposals are therefore strongly encouraged to include plans, or begin preparing to include plans, for broadening participation activities in the Broader Impacts sections of their proposals.

#### 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 **must** include all PIs, Co-PIs, Senior Personnel, paid/unpaid Consultants or Collaborators, Subawardees, Postdocs, and project-level advisory committee members. This list should be numbered and include (in this order) Full name, Organization(s), and Role in the project, with each item separated by a semi-colon. Each person listed should start a new numbered line. For example:

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 for Medium projects (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 Medium projects that include more than one investigator must include a Collaboration Plan of up to 2 pages**. The length of and degree of detail provided in the Collaboration Plan should be commensurate with the complexity of the proposed project. Where appropriate, the Collaboration Plan might include: 1) the specific roles of the project participants in all organizations involved; 2) information on how the project will be managed across all the investigators, 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 conferences, graduate student exchange, project meetings at conferences, use of the grid for videoconferences, software repositories, etc.); and 4) specific references to the budget line items that support collaboration and coordination mechanisms. **If a Medium 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. *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](https://www.nsf.gov/cise/cise_dmp.jsp).

4. *Broadening Participation in Computing (BPC) Plans for Medium projects:*

Each Medium project must, by the time of award, have in place an approved BPC plan. In this ongoing pilot phase, CISE will work with each PI team prior to making an award to ensure that plans are meaningful and include concrete metrics for success. CISE will also provide opportunities for PIs to share BPC experiences and innovations through program PI meetings. PIs of Medium proposals are therefore strongly encouraged to consider this eventual requirement as they develop their proposals, and to include descriptions (of one to three pages) of their planned BPC activities under Supplementary Documents in their submissions. Feedback will be provided on such plans.

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.**

6. *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.

GOALI proposals: PIs submitting GOALI proposals should include industry-university agreement letters on intellectual property

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.

Collaborators and Other Affiliations due to participants listed on item (1) under Supplementary Documents above who are not PIs, co-PIs, or Senior Personnel can be uploaded under Additional Single Copy Documents using Transfer File.

#### Submission Checklist:

In an effort to assist proposal preparation, the following checklists are provided as a reminder of the items that should be checked before submitting an AF, CIF, FET or SHF proposal to this solicitation. These are a summary of the requirements described above. For the items marked with (RWR), the proposal will be returned without review if the required item is noncompliant at the submission deadline. Note that there are three lists: (1) for all proposals, unique to this solicitation; (2) additional requirements for Small proposals; and (3) additional requirements for Medium proposals.

1. *For all proposals, regardless of size:*
  - The last line of the Overview section of the Project Summary should consist of the word "Keywords" followed by a colon and between 2-6 keyword sets, separated by semi-colons.
2. *For Small proposals:*
  - The proposal title should comply with the requirements under Proposal Preparation Instructions.
  - In addition to the above title prefixes, proposals from PIs in institutions that have RUI (Research in Undergraduate Institutions) eligibility should include "RUI:" immediately before the proposal title, for example, **SHF: Small: RUI: Title**, and should include a Research in Undergraduate Institutions Impact Statement and Certification of RUI Eligibility. Similarly, PIs submitting Grant Opportunities for Academic Liaison with Industry (GOALI) proposals should select "GOALI" from the Type of Proposal drop down list in the Proposal Preparation module in FastLane or Grants.gov; and include "GOALI:" immediately before the proposal title, for example, **AF: Small: GOALI: Title**.
  - (RWR) Maximum budget shown on the Cover Sheet and on the budget pages must not exceed \$500,000, including all institutions in a collaborative proposal, plus funds for embedded REU supplements.
  - (RWR) The Project Description is limited to no more than 15 pages.
  - A Collaboration Plan (up to 2 pages) **may** be provided as a Supplementary Document. If provided, the collaboration plan should include all institutions participating, not a separate plan for each institution.
3. *For Medium proposals:*
  - The proposal title should comply with the requirements under Proposal Preparation Instructions.
  - In addition to the above title prefixes, proposals from PIs in institutions that have RUI (Research in Undergraduate Institutions) eligibility should include "RUI:" immediately before the proposal title, for example, **CIF: Medium: RUI: Title**, and should include a Research in Undergraduate Institutions Impact Statement and Certification of RUI Eligibility. Similarly, PIs submitting Grant Opportunities for Academic Liaison with Industry (GOALI) proposals should select "GOALI" from the Type of Proposal drop down list in the Proposal Preparation module in FastLane or Grants.gov; and include "GOALI:" immediately before the proposal title, for example, **FET: Medium: GOALI: Title**.
  - (RWR) The budget shown on the Cover Sheet and on the budget pages **must** be \$500,001 to \$1,200,000, including all institutions in a collaborative proposal, plus funds for embedded REU supplements.
  - (RWR) The Project Description is limited to no more than 15 pages.
  - (RWR) If there is more than one investigator, a Collaboration Plan (up to 2 pages) **must** be provided as a Supplementary Document, even if all investigators are affiliated with the same institution. The Collaboration Plan should include all institutions participating, not a separate plan for each institution.
  - A BPC Plan (of one to three pages) should be provided as a Supplementary Document.

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

## B. Budgetary Information

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#### Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

#### Other Budgetary Limitations:

Budgets must comply with the range limitations specified for each project class.

## C. Due Dates

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- **Submission Window Date(s)** (due by 5 p.m. submitter's local time):

September 24, 2018 - October 02, 2018

MEDIUM projects

November 01, 2018 - November 15, 2018

SMALL projects

September 09, 2019 - September 16, 2019

MEDIUM projects

October 31, 2019 - November 14, 2019

SMALL projects

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

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### For Proposals Submitted Via FastLane or Research.gov:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: <https://www.fastlane.nsf.gov/a1/newstan.htm>. To prepare and submit a proposal via Research.gov, see detailed technical instructions available at: [https://www.research.gov/research-portal/appmanager/base/desktop?\\_nfpb=true&\\_pageLabel=research\\_node\\_display&\\_nodePath=/researchGov/Service/Desktop/ProposalPreparationandSubmission.html](https://www.research.gov/research-portal/appmanager/base/desktop?_nfpb=true&_pageLabel=research_node_display&_nodePath=/researchGov/Service/Desktop/ProposalPreparationandSubmission.html). For FastLane or Research.gov user support, call the FastLane and Research.gov Help Desk at 1-800-673-6188 or e-mail [fastlane@nsf.gov](mailto:fastlane@nsf.gov) or [rgov@nsf.gov](mailto:rgov@nsf.gov). The FastLane and Research.gov Help Desk answers general technical questions related to the use of the FastLane and Research.gov systems. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

### For Proposals Submitted Via Grants.gov:

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. Comprehensive information about using Grants.gov is available on the Grants.gov Applicant Resources webpage: <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](mailto:support@grants.gov). The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this solicitation.

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

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

## VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

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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/](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

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

### 1. Merit Review Principles

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

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

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

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

### 2. Merit Review Criteria

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

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

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

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

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

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



proposed activities?

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

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

#### **Additional Solicitation Specific Review Criteria**

For Medium proposals, reviewers will be asked to:

- Comment on the extent to which the project scope justifies the level of investment requested, and the degree to which the Collaboration Plan (if applicable) adequately demonstrates that the participating investigators will work synergistically to accomplish the project objectives.
- Comment on whether key personnel, and especially lead PIs, have allocated adequate time for both their individual technical contributions and the leadership of collaborative activities necessary to realize the synergistic effects of larger-scale research.

## **B. Review and Selection Process**

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

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**

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### **A. Notification of the Award**

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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**

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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](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](mailto: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](https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg).

## C. Reporting Requirements

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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](https://www.nsf.gov/publications/pub_summ.jsp?ods_key=pappg).

## VIII. AGENCY CONTACTS

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*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, Point of Contact, Software and Hardware Foundations (SHF), telephone: (703) 292-8910, email: [abanerje@nsf.gov](mailto:abanerje@nsf.gov)
- Mitra Basu, Point of Contact, Foundations of Emerging Technologies (FET), telephone: (703) 292-8910, email: [mbasu@nsf.gov](mailto:mbasu@nsf.gov)
- Tracy Kimbrel, Point of Contact, Algorithmic Foundations (AF), telephone: (703) 292-8910, email: [tkimbrel@nsf.gov](mailto:tkimbrel@nsf.gov)
- Dmitry Maslov, Point of Contact, Foundations of Emerging Technologies (FET), telephone: (703) 292-8910, email: [dmaslov@nsf.gov](mailto:dmaslov@nsf.gov)
- Phillip Regalia, Point of Contact, Communications and Information Foundations (CIF), telephone: (703) 292-8910, email: [pregalia@nsf.gov](mailto:pregalia@nsf.gov)

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

- FastLane and Research.gov Help Desk: 1-800-673-6188  
FastLane Help Desk e-mail: [fastlane@nsf.gov](mailto:fastlane@nsf.gov)  
Research.gov Help Desk e-mail: [rgov@nsf.gov](mailto: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](mailto:support@grants.gov).

In addition to the Program Officers identified as program points of contact above, the following CCF Program Officers also support CCF



core programs as indicated below:

#### Algorithmic Foundations (AF)

- Rahul Shah, (703) 292-8910 [rshah@nsf.gov](mailto:rshah@nsf.gov)

#### Software and Hardware Foundations (SHF)

- Nina Amla, (703) 292-8910, [namla@nsf.gov](mailto:namla@nsf.gov)
- Sankar Basu, (703) 292-8910, [sabasu@nsf.gov](mailto:sabasu@nsf.gov)
- Almadena Chtchelkanova, (703) 292-8910, [achtchel@nsf.gov](mailto:achtchel@nsf.gov)
- Sol Greenspan, (703) 292-8910, [sgreensp@nsf.gov](mailto:sgreensp@nsf.gov)
- Yuanyuan Yang, (703) 292-8910, [yyang@nsf.gov](mailto:yyang@nsf.gov)

## IX. OTHER INFORMATION

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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

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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.

*Facilitation Awards for Scientists and Engineers with Disabilities (FASSED)* 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](mailto:nsfpubs@nsf.gov)

or telephone: (703) 292-7827

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

## PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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

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

Suzanne H. Plimpton  
Reports Clearance Officer  
Office of the General Counsel  
National Science Foundation  
Arlington, VA 22230

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