

Energy-Efficient Computing: from Devices to Architectures (E2CDA)

A Joint Initiative between NSF and SRC

PROGRAM SOLICITATION

NSF 17-531

REPLACES DOCUMENT(S):

NSF 16-526



National Science Foundation

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

Directorate for Engineering
Division of Electrical, Communications and Cyber Systems



Semiconductor Research Corporation

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

March 07, 2017

IMPORTANT INFORMATION AND REVISION NOTES

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide (PAPPG) (NSF 17-1)*, which is effective for proposals submitted, or due, on or after January 30, 2017. Please be advised that proposers who opt to submit prior to January 30, 2017, must also follow the guidelines contained in [NSF 17-1](#).

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Energy-Efficient Computing: from Devices to Architectures (E2CDA)
A Joint Initiative between NSF and SRC

Synopsis of Program:

There is a consensus across the many industries touched by our ubiquitous computing infrastructure that future performance improvements across the board are now severely limited by the amount of energy it takes to manipulate, store, and critically, transport data. While the limits and tradeoffs for this performance-energy crisis vary across the full range of application platforms, they have all reached a point at which evolutionary approaches to addressing this challenge are no longer adequate.

Truly disruptive breakthroughs are now required, and not just from any one segment of the technology stack. Rather, due to the complexity of the challenges, revolutionary new approaches are needed at each level in the hierarchy. Furthermore, simultaneous co-optimization across all levels is essential for the creation of new, sustainable computing platforms.

These simultaneous technical and organizational challenges have never been as complex or as critically important as they are now. The urgency of solving the multi-disciplinary technical challenges will require new methods of collaboration and organization among researchers.

Therefore, a comprehensive and collaborative approach must be undertaken to maximize the potential for successfully identifying and implementing revolutionary solutions to break through the bottleneck of energy-constrained computational performance. Programmers, system architects, circuit designers, chip processing engineers, material scientists, and computational chemists must all explore these new paths together to co-design an optimal solution path.

The National Science Foundation (NSF) and the Semiconductor Research Corporation (SRC) recognize this need, and agree to embark on a new collaborative research program to support compelling research that is of paramount importance to industry, academia and society at large. This partnership will specifically support new research to

minimize the energy impacts of processing, storing, and moving data within future computing systems, and will be synergistic with other research activities that address other aspects of this overarching energy-constrained computing performance challenge.

The jointly supported research effort aligns with interagency initiatives and priorities, including the [National Strategic Computing Initiative](#) and the [nanotechnology-inspired Grand Challenge for Future Computing](#).

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.

- Sankar Basu, Program Director, Computing & Communication Foundations Division, NSF, telephone: (703) 292-7843, email: sabasu@nsf.gov
- Dimitris Pavlidis, Program Director, Electrical, Communications & Cyber Systems Division, NSF, telephone: (703) 292-2216, email: dpavli@nsf.gov
- An Chen, Executive Director, Semiconductor Research Corporation, telephone: (914) 945-2244, email: an.chen@src.org

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

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

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 4 to 8

Each project will be jointly funded by NSF and the SRC through separate NSF and SRC funding instruments. For each project, NSF support will be provided via an NSF grant and SRC support will be provided via an SRC contract or grant. Approximately 2 to 4 multidisciplinary collaborative (Type I) awards and 2 to 4 individual or small (Type II) awards will be made, subject to the availability of funds and quality of proposals.

Anticipated Funding Amount: \$6,000,000

The total amount of funds anticipated for this solicitation is up to \$6,000,000 per year subject to the availability of funds. It is anticipated that approximately 2-4 multidisciplinary collaborative (Type I) projects, each ranging from \$800,000 to \$1,600,000 per year for three 3 years, and 2-4 individual or small (Type II) projects, each ranging from \$100,000 to \$200,000 per year for 1 to 3 years, will be supported.

Eligibility Information

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Universities and Colleges - Universities and two- and four-year colleges (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An investigator may participate as PI or co-PI on no more than one proposal submitted in response to this solicitation.

In the event that an individual exceeds this limit, proposals will be accepted based on earliest date and time of proposal submission, i.e., the first proposal received will be accepted and the remainder will be returned without review. No exceptions will be made.

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

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Not required
- **Preliminary Proposal Submission:** Not required
- **Full Proposals:**
 - Full Proposals submitted via FastLane: *NSF Proposal and Award Policies and Procedures Guide (PAPPG)*

guidelines apply. The complete text of the PAPPG is available electronically on the NSF website at:

https://www.nsf.gov/publications/pub_summ.jsp?ods_key=papp.

- o 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: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide).

B. Budgetary Information

- **Cost Sharing Requirements:**

Inclusion of voluntary committed cost sharing is prohibited.

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

Not Applicable

- **Other Budgetary Limitations:**

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

C. Due Dates

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

March 07, 2017

Proposal Review Information Criteria

Merit Review Criteria:

National Science Board approved criteria apply.

Award Administration Information

Award Conditions:

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

Reporting Requirements:

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

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I. INTRODUCTION

The National Science Foundation (NSF), through its Division of Computing and Communication Foundations (CCF) within the Directorate for Computer and Information Science and Engineering (CISE) and Division of Electrical, Communications and Cyber Systems (ECCS) within the Directorate for Engineering has established a partnership with the Semiconductor Research Corporation (SRC), through its Global Research Collaboration (GRC) and Nanoelectronics Research Initiative (NRI) programs, to jointly support innovative research activities focused on exploring and dramatically extending the limits of computational energy efficiency for a broad range of applications.

The jointly supported research effort aligns with interagency initiatives and priorities, including the [National Strategic Computing Initiative](#) and the [nanotechnology-inspired Grand Challenge for Future Computing](#).

There is a consensus across the vast ecosystem touched by our ubiquitous computing infrastructure that performance improvements across most all application spaces are now severely limited by the energy dissipation involved in processing, storing, and moving data. While the tradeoffs between system performance and energy dissipation vary across the range of application platforms, nearly all applications are constrained by physical and associated economic limits to acceptable energy dissipation. Evolutionary approaches to address this challenge are becoming increasingly ineffective.

In addition, the exponential increase in the volume of data to be handled by our computational infrastructure is driven in large part by unstructured data from nearly countless sources. Conventional computing architectures and programming platforms are unable to deal effectively or efficiently with this volume or with the requirement to transform such data into actionable information.

These challenges have never been as complex or as critically important as they are now. The urgency of solving them to create a new computing paradigm will require pervasive and direct collaboration and organization of the research to drive operational efficiency and maximize the chance for success. A truly holistic and collaborative approach must be adopted and supported by researchers in order to maximize the potential for successfully identifying and implementing comprehensive solutions.

Collaborative, multi-disciplinary proposals that address one or both of the following research paths are solicited: (1) disruptive system architectures, circuit microarchitectures, and attendant device and interconnect technology aimed at achieving the highest level of computational energy efficiency; and (2) revolutionary device concepts and associated circuits and architectures that will greatly extend the practical engineering limits of energy-efficient computation. Further details on these research thrusts are described in the Program Description section of this solicitation.

All proposals should aim for scalability sufficient to address application platforms from mobile devices to data centers, as well as extensible solutions that will sustain the long-term vitality of the information technology ecosystem.

II. PROGRAM DESCRIPTION

Multi-disciplinary and directly collaborative proposals are solicited for foundational and transformative research in devices, circuit microarchitectures, and system architectures. Proposers should strive to identify comprehensive approaches to greatly reduce the energy dissipation in future data-intensive computing systems while also enhancing system performance. While a comprehensive solution to this problem will ultimately require co-optimization with application software, this solicitation is focused on exploration and demonstration of the necessary materials, devices, and circuit and system hardware architectures, and not on the accompanying software architectures.

Within this intellectual framework, submitted proposals should address one or both of the following research paths and should comprehensively address the most aggressive goals within the chosen approach. While, as just mentioned, the main goal of this program is to support multidisciplinary collaborative team efforts (Type I proposals) involving one or both of the following two categories, a few smaller and more focused small efforts (Type II proposals) within the general context of the research areas described here may be entertained as well.

1. Disruptive system architectures, circuit microarchitectures, and attendant device and interconnect technology aimed at achieving the highest level of computational energy efficiency

Collaborative and cross-disciplinary proposals for creating revolutionary system architectures and circuit microarchitectures that will overcome the energy and delay barriers associated with the movement of data in conventional interconnect technologies, and will also drive a new scalable and sustainable computational paradigm, are sought within the scope of this program.

The proposals must target at least a 100X reduction or more in energy per delivered operation as compared to projected high-performance computing (HPC) systems utilizing conventional CMOS architectures and deeply scaled technology at the end of the roadmap. As just one example of a metric goal, demonstrations that achieve system-level performance of > 1 Giga-MAC/s/nW could be targeted (MAC = multiply and accumulate operations).

Proposals that utilize alternative connectivity technologies such as plasmonic, photonic, terahertz or any others that can enable a dramatic lowering of overall system energy dissipation are also of interest. Interconnect technologies that enable functionality (such as embedded 'intelligent' routing, etc.) beyond point-to-point connectivity and the architectures that implement them are also within the scope of interest.

In addition, proposals are strongly encouraged to include an approach for merging heuristic learning and predictive functionality on the same physical platform as a programmable algorithmic capability. Metrics should also be suggested to measure progress in both the heuristic portion of the common platform (e.g., 'energy-to-solution', etc.), as well as, the energy efficiency and performance of the programmable portions.

Proposed research examples may include non-digital or hybrid digital-analog architectures: non-Boolean, brain-inspired architectures including reservoir computing and other neuro-inspired approaches: stochastic, approximate, memory-centric or merged logic-memory; or other such fundamentally novel, heterogeneous architectures aimed at achieving the minimum levels of energy-per-delivered programmable operation, while at the same time augmenting the overall system performance with learning and predictive capabilities. Novel designs that can physically demonstrate and verify any predicted performance within the scope of the proposed research proposal are strongly preferred.

"Sprinting" architectures allow portions of a system to briefly exceed time-averaged power dissipation limits, in order to accelerate operations that are critical to overall system performance. Proposals for novel sprinting architectures, offering dramatic improvements in power-performance trade-off, are also encouraged.

Some specific (but non-exhaustive) examples of research topics *not* sought in this program include incremental research in any of

these areas:

- Evolutionary extensions of existing general purpose computing platform architectures;
- Systems that preclude substantially expanding the functionality and performance capabilities of general purpose computing, even if they are also aimed at significantly improving the overall level of energy efficiency;
- System architectures that cannot be demonstrated to economically support the levels of reliability and physical dimension requirements projected for the future applications being targeted; and
- System architectures that are not sufficiently scalable to support a broad base of applications, i.e., those that do not enable a common, fundamental platform sufficiently capable of addressing applications from high-performance mobile devices to data centers.

2. Revolutionary device concepts and associated circuits and architectures that will greatly extend the practical engineering limits of energy-efficient computation

Proposals for the demonstration of new device concepts with the potential to reduce the energy dissipation involved in processing, storing, and moving information by two or more orders of magnitude are sought. Proposals should address interdisciplinary research issues essential to the demonstration of the device concept – from optimization of material properties to development of appropriate circuits and architectures. Any new switch is likely to have characteristics very different from those of a conventional field effect transistor. The interplay between device characteristics and optimum circuit architectures therefore means that circuit architectures must be reconsidered – this includes digital circuits, but also analog, memory, communication, and/or other more specialized functions. Devices combining digital/analog/memory functions may lend themselves particularly well to unconventional information processing architectures. Proposed architectures should enable a broad range of useful functions, rather than being dedicated to one function or a few particular functions.

New physical mechanisms for digital switching are of interest, and many dynamical systems may deserve exploration. For example, the gating of phase transitions is a potential route to “steep slope” devices that operate at very low voltage. Relevant phase transitions might include metal-insulator transitions, formation of excitonic or other electronic condensates, and various transitions involving structural degrees of freedom. Other promising mechanisms for low-power switching may involve transduction. Magnetoelectric devices, in which an external voltage state is transduced to an internal magnetic state, exemplify this concept. However, transduction need not be limited to magnetoelectric systems.

In addition to energy efficiency, switching speed is an important criterion in choice of materials and device concepts. For example, most nanomagnetic devices switch by magnetic precession, a process that is rather slow in the ferromagnetic systems explored to date. Magnetic precession switching in antiferromagnetic or ferrimagnetic materials could be one or more orders of magnitude faster. Other novel physical systems could be faster still. For example, electronic collective states could, in principle, be switched on sub-picosecond time scales.

More generally, devices based on computational state variables beyond magnetism and charge (or voltage) could open many new possibilities.

Another relatively unexplored path to improved energy efficiency is the implementation of adiabatically-switched devices in energy-conserving circuits. In such circuits, the phase of an oscillation or propagating wave may represent digital state; devices and interconnections must together constitute circuits that are non-dissipative. Nanophotonic, plasmonic, spinwave or other lightly-damped oscillatory systems might be well-suited for such an approach. Proposals along these lines should strive to address the necessary components of a practical engineering solution, including mechanisms for correction of unavoidable phase and amplitude errors.

Networks of coupled non-linear oscillators have also been explored for non-Boolean computation in applications such as pattern recognition. Potential technological approaches include but are not limited to nanoelectromechanical, nanophotonic, nanoplasmonic, and nanomagnetic oscillators. Proposals along these lines should strive to address the necessary components of a practical engineering solution, including devices, circuits, and architectures that allow reliable operation in the presence of device variability and environmental fluctuations.

While appropriate circuits and higher-level architectures should be explored and co-developed along with any new device concept, certain novel device concepts may demand greater emphasis on higher-level architecture. For example, hysteretic devices, combining the functions of non-volatile logic and memory, might enhance the performance of established architectures (power gating in microprocessors, reconfiguration of logic in field programmable gate arrays), but perhaps more importantly, they might play an enabling role in novel architectures (compute in memory, weighting of connections in neuromorphic systems, and more). As a second example, there has been great progress in recent years in the miniaturization and energy efficiency of linear and non-linear photonic devices. It is possible that these advances will have their greatest impact not in the ongoing replacement of metal wires by optical connections, but rather in enabling new architectures for computing. Computation “in the network” is one possible direction. In general, device characteristics and architecture appear to be highly entwined in oscillatory (approximately energy-conserving) systems. Key device characteristics may be inseparable from the coupling (connections) between devices. For non-Boolean computation, optimum architectures and the range of useful algorithms will depend on these characteristics.

In addition to the examples above, proposers are encouraged to champion other areas of architectural research that could leverage emerging device concepts to obtain order of magnitude improvements in the energy efficiency of computing. Research topics might include architectures for heterogeneous systems, architectures that minimize data movement, neuromorphic architectures, and new approaches to stochastic computing and approximate computing.

Some specific (but non-exhaustive) examples of research topics *not* sought in this program include research in any of these areas:

- Materials or device concepts that incrementally extend the capabilities of commercially established devices for logic and memory;
- CMOS-based approaches to energy-conserving circuits and architectures;
- Device concepts that are already the focus of research within established projects and centers, unless the proposed research is a substantive step beyond the currently-funded research;
- Highly-specialized circuit architectures (“accelerators”) suited to a particular function or a limited set of functions, unless these circuits can be envisioned as economically integrated in a hybrid system capable of more generalized functions; and
- Devices and architectures for quantum computing - although proposals that explore the semi-classical regime (perhaps instantiating state variables with small ensembles of quantum states) or proposals that embrace some attributes of quantum computing achievable in the classical limit (such as energy-conserving circuits) are welcome.

III. AWARD INFORMATION

Anticipated Type of Award: Continuing Grant or Standard Grant

Estimated Number of Awards: 4 to 8

Each project will be jointly funded by NSF and the SRC through separate NSF and SRC funding instruments. For each project, NSF support will be provided via an NSF grant and SRC support will be provided via an SRC contract or grant. Approximately 2 to 4 multidisciplinary collaborative (Type I) awards and 2 to 4 individual or small (Type II) awards will be made, subject to the availability of funds and quality of proposals.

Anticipated Funding Amount: \$6,000,000

The total amount of funds anticipated for this solicitation is up to \$6,000,000 per year subject to the availability of funds. It is anticipated that approximately 2-4 multidisciplinary collaborative (Type I) projects, each ranging from \$800,000 to \$1,600,000 per year for three 3 years, and 2-4 individual or small (Type II) projects, each ranging from \$100,000 to \$200,000 per year for 1 to 3 years, will be supported.

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

IV. ELIGIBILITY INFORMATION

Who May Submit Proposals:

Proposals may only be submitted by the following:

- Universities and Colleges - Universities and two- and four-year colleges (including community colleges) accredited in, and having a campus located in, the US acting on behalf of their faculty members. Such organizations also are referred to as academic institutions.

Who May Serve as PI:

There are no restrictions or limits.

Limit on Number of Proposals per Organization:

There are no restrictions or limits.

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

An investigator may participate as PI or co-PI on no more than one proposal submitted in response to this solicitation.

In the event that an individual exceeds this limit, proposals will be accepted based on earliest date and time of proposal submission, i.e., the first proposal received will be accepted and the remainder will be returned without review. No exceptions will be made.

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

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

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

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

on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

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

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

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

Proposal titles must start with **E2CDA** followed by a colon, then specify the class (**Type I** or **Type II**) followed by a colon, and then provide the title of the project. That is, the title for a Type 1 proposal may take the form **E2CDA: Type I: Title**. For a collaborative proposal (that is, one submitted as separate submissions from multiple organizations), all participating institutions should use the same title, which should also include the phrase Collaborative Research followed by a colon, e.g., **E2CDA: Type II: Collaborative Research: Title**.

Budget:

Grantees of this program receiving funds from the SRC will be expected to attend, and shall budget for, annual SRC grantee review meetings for the purpose of sharing research progress with SRC member company representatives as well as other interested individuals.

Supplementary Documents:

1) Statement of Consent:

In order to be considered for funding through this program, each proposal **must** include a statement of consent from the proposing institution(s) that indicates that NSF may share with SRC the proposal, reviews generated for the proposal, and any related information. This statement of consent must be uploaded into the Supplementary Documents section in FastLane or Grants.gov. Proposals that do not contain this statement will be returned without review.

2) Disclosure of Blocking Background IP:

All proposals must include a statement disclosing any background intellectual property (IP) known to the proposer that is expected to block the freedom to practice the results of the proposed research. Whereas SRC is entitled to a royalty-free, non-exclusive license only to practice any IP that directly results from activities funded by NSF/SRC joint funding, SRC must resolve issues regarding blocking IP prior to awarding an SRC contract. For example, SRC may negotiate a license to blocking IP. NSF funding will not be contingent upon resolution of any blocking IP, and funding by SRC or NSF will not create an obligation for the other organization to provide funds.

3) Industry Involvement:

For proposals involving academic institutions and industry, proposers should include a letter from the industrial partner(s) that confirm(s) the participation of one or more co-PIs from industry. This letter, uploaded in the Supplementary Documents section in FastLane or Grants.gov, should describe a plan for interaction between the industrial and academic partners, the time commitment of the industrial researcher(s), and the nature of the work.

4) List of Project Personnel and Partner Institutions (Note - In collaborative proposals, only the lead institution should provide this information):

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 find reviewers who are not conflicted with proposals. The list should include all PIs, Co-PIs, Senior Personnel, paid/unpaid Consultants or Collaborators, Sub awardees, Postdocs, and project-level advisory committee members. This list should be numbered, in alphabetical order by last name, and include for each entry (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 Adams; XYZ University; PI
2. John Brown; University of PQR; Senior Personnel
3. Jane Green; XYZ University; Postdoc
4. Bob Jones; ABC Inc.; Paid Consultant
5. Tim White; ZZZ University; Subawardee

Single Copy Documents:

Collaborators and Other Affiliations Information:

For this solicitation, the *Collaborators & Other Affiliations* information specified in the PAPPG should be submitted using the spreadsheet template found at <https://www.nsf.gov/cise/collab/>. For each proposal, a completed spreadsheet for each PI, co-PI, or senior personnel must be uploaded directly into Fastlane in .xls or .xlsx format as a "Collaborator and Other Affiliations" Single Copy Document. NSF staff use this information in the merit review process to help manage reviewer selection; the spreadsheet will ensure the Collaborator and Other Affiliations information has a common, searchable format.

Note the distinction to (4) above for Supplementary Documents: the listing of all project participants is collected by the project lead and entered as a Supplementary Document, which is then automatically included with all proposals in a project. The Collaborators and Other Affiliations are entered for each participant within each proposal and, as Single Copy Documents, are available only to NSF staff. Collaborators and Other Affiliations due to participants listed on (4) that are not PIs, co-PIs, or senior personnel can be uploaded under Additional Single Copy Documents using Transfer File.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

Other Budgetary Limitations:

Researchers from foreign academic institutions who contribute essential expertise to the project may participate as co-PIs or senior personnel but may not request NSF or SRC support. Given that no person months and no salary are being requested for such individuals, they must be removed from section A of the budget. This can be done by clicking on the name(s) in the NSF budget format and then clicking "Check to remove". Their name(s) will remain on the Cover Sheet and the individual(s) role on the project should be described in the Facilities, Equipment and Other Resources section of the proposal.

Synergistic collaborations or partnerships with industry or government are allowed when appropriate, though no NSF or SRC funds will be provided to these organizations.

Budget Preparation Instructions:

Proposals submitted to NSF via FastLane or Grants.gov should contain budget information for the entire project in the standard NSF format. PIs of proposals recommended for award will be requested to submit a revised budget to NSF and SRC, as appropriate. For those proposals recommended for joint funding by NSF and SRC, the revised budget submitted to NSF will include the NSF portion of the budget in the standard NSF format, a copy of the budget being submitted separately to SRC, and a detailed breakdown of the activities being funded by NSF and SRC.

C. Due Dates

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

March 07, 2017

D. FastLane/Grants.gov Requirements

For Proposals Submitted Via FastLane:

To prepare and submit a proposal via FastLane, see detailed technical instructions available at: <https://www.fastlane.nsf.gov/a1/newstan.htm>. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov. The FastLane Help Desk answers general technical questions related to the use of the FastLane system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

For Proposals Submitted Via Grants.gov:

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

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

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

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

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

A comprehensive description of the Foundation's merit review process is available on the NSF website at: http://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 *Investing in Science, Engineering, and Education for the Nation's Future: NSF Strategic Plan for 2014-2018*. These strategies are integrated in the program planning and implementation process, of which proposal review is one part. NSF's mission is particularly well-

implemented through the integration of research and education and broadening participation in NSF programs, projects, and activities.

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

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

A. Merit Review Principles and Criteria

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

1. Merit Review Principles

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

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

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

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

2. Merit Review Criteria

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

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

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

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

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

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

Broader impacts may be accomplished through the research itself, through the activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. NSF values the advancement of scientific knowledge and activities that contribute to achievement of societally relevant outcomes. Such outcomes include, but are not limited to: full participation of women, persons with disabilities, and underrepresented minorities in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and

public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the United States; and enhanced infrastructure for research and education.

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

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by 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 be completed and submitted by each reviewer. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

NSF will manage and conduct the review process of proposals submitted in accordance with NSF standards and procedures. The review and award recommendations will be coordinated by a Joint Working Group (JWG) of program officers from both NSF and SRC. Relevant information about proposals and reviews of proposals will be shared between NSF and the SRC program officers as appropriate. The JWG will recommend meritorious proposals for award at appropriate funding levels.

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

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

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

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

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

B. Award Conditions

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

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

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

Special Award Conditions:

Individual awards will be jointly funded by NSF and SRC through separate NSF and SRC funding instruments. NSF awards will be made as continuing or standard grants. SRC awards will be made as SRC contracts or grants. For each award, NSF and SRC contributions will be in proportion to their overall contributions to the program. Beyond the base level of support, either organization may supplement a project for special purposes, such as education or development, without requiring the other party to provide any additional funds. NSF/SRC awards will be made for one- to three-year periods.

All joint or separate awards involving an SRC contract must also include an executed agreement on intellectual property, including publications and patent rights, signed by the representatives of the awardee organization and SRC. SRC contracts provide for non-exclusive, royalty free rights to all SRC members for any intellectual property generated as a result of SRC-funded research. All issues regarding blocking IP must be resolved before an SRC contract is awarded.

C. Reporting Requirements

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

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

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

More comprehensive information on NSF Reporting Requirements and other important information on the administration of NSF awards is contained in the *NSF Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag.

NSF and SRC will manage their respective awards/contracts in accordance with their own guidelines. Awardees will submit annual project reports to NSF via Research.gov, subject to NSF procedures. Awardees will also submit annual reports to SRC, subject to SRC procedures.

SRC will organize and conduct annual reviews and will require certain deliverable reports to monitor the program and project progress. SRC will seek to provide structured involvement of industry in the research and review process and will undertake the organization and cost of the annual review.

Grantees of this program receiving SRC funds will be expected to attend, and shall budget for, annual SRC grantee review meetings for the purpose of sharing research progress with SRC member company representatives as well as other interested individuals. Thirty days before each of these meetings, the principal investigator will provide SRC an annotated PowerPoint viewgraph presentation of research results for posting on the SRC website.

VIII. AGENCY CONTACTS

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

General inquiries regarding this program should be made to:

- Sankar Basu, Program Director, Computing & Communication Foundations Division, NSF, telephone: (703) 292-7843, email: sabasu@nsf.gov
- Dimitris Pavlidis, Program Director, Electrical, Communications & Cyber Systems Division, NSF, telephone: (703) 292-2216, email: dpavli@nsf.gov
- An Chen, Executive Director, Semiconductor Research Corporation, telephone: (914) 945-2244, email: an.chen@src.org

For questions related to the use of FastLane, contact:

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

For questions relating to Grants.gov contact:

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

IX. OTHER INFORMATION

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

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding

opportunities may be accessed via this mechanism. Further information on Grants.gov may be obtained at <http://www.grants.gov>.

ABOUT THE NATIONAL SCIENCE FOUNDATION

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

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

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

Facilitation Awards for Scientists and Engineers with Disabilities (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 <http://www.nsf.gov>

- **Location:** 4201 Wilson Blvd. Arlington, VA 22230
- **For General Information**
(NSF Information Center): (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**
Send an e-mail to: nsfpubs@nsf.gov
or telephone: (703) 292-7827
- **To Locate NSF Employees:** (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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

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

Suzanne H. Plimpton
Reports Clearance Officer
Office of the General Counsel
National Science Foundation



The National Science Foundation, 4201 Wilson Boulevard, Arlington, Virginia 22230, USA
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