Scalable Nanomanufacturing for Integrated Systems (SNM-IS)

PROGRAM SOLICITATION
NSF 16-604

REPLACES DOCUMENT(S):
NSF 16-513

National Science Foundation

Directorate for Engineering
Division of Civil, Mechanical and Manufacturing Innovation
Division of Electrical, Communications and Cyber Systems
Division of Chemical, Bioengineering, Environmental and Transport Systems
Engineering Education and Centers
Industrial Innovation and Partnerships

Directorate for Mathematical & Physical Sciences
Division of Materials Research

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

January 13, 2017

IMPORTANT INFORMATION AND REVISION NOTES

The Scalable Nanomanufacturing for Integrated Systems (SNM-IS) solicitation is changed from the previous Scalable Nanomanufacturing (SNM) solicitation in that the objective has shifted from research in large-scale manufacturing of single-component nanomaterials and nanostructures to investigations in scalable nanomanufacturing and integration of multi-component nano-enabled integrated systems. The emphasis is to frame proposals in the context of the realization of integrated systems for the eventual economic manufacture of demonstrably useful nano-enabled products in high volume or customized products in low volume, responsibly and safely. An integrated system is a system that combines different functions together to work as one entity. System integration is the process of assembling component subsystems such that the subsystems function together as a system.

Any proposal submitted in response to this solicitation should be submitted in accordance with the revised *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) (NSF 16-1), which is effective for proposals submitted, or due, on or after January 25, 2016. Please be advised that proposers who opt to submit prior to January 25, 2016, must also follow the guidelines contained in NSF 16-1.

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

Scalable Nanomanufacturing for Integrated Systems (SNM-IS)

Synopsis of Program:

The National Science Foundation (NSF) announces a 7th (seventh) year of a solicitation on collaborative research and education in the area of Scalable Nanomanufacturing for Integrated Systems (SNM-IS). This solicitation is in response to and is a component of the National Nanotechnology Initiative (NNI) Signature Initiative: Sustainable Nanomanufacturing - Creating the Industries of the Future (http://www.nano.gov/NSINanomanufacturing).

Many nanofabrication techniques have demonstrated the ability to synthesize small quantities of nanomaterials and nanostructures for characterization and evaluation and simple nanodevices for analysis and testing purposes. The emphasis of the Scalable Nanomanufacturing for Integrated Systems (SNM-IS) solicitation is on research in new nano-scale manufacturing concepts and integration methods to realize complex integrated systems based on nanotechnology. The research will focus on overcoming the key scientific and engineering barriers that prevent the translation of laboratory-scale discoveries in nano-enabled integrated systems to an industrially relevant scale, reliably, affordably and within sustainability and environmental, health and safety (EHS) guidelines. The goal of the SNM-IS solicitation is to study and formulate the fundamental principles of scalable nanomanufacturing and integration for nanotechnology-based integrated systems towards the eventual manufacture of useful nano-enabled products.

The SNM-IS solicitation is driven by the discovery of numerous new nanomaterials with unique properties (2D atomic layer, transition metal dichalcogenides, van der Waals heterostructures, perovskites, metal-organic frameworks, metamaterials, origami, etc.) in recent years and invention of many novel fabrication methods (nano additive manufacturing, strain engineering processing, bio-nanomanufacturing, etc.) to synthesize nanostructures

with different geometries, 'microstructures' and functionalities. These nanomaterials and nanostructures need to be assembled into larger-scale components and devices, which, in turn, need to be integrated into higher-order subsystems and systems so novel and useful products can be made for a variety of applications in the areas of functional and structural materials, mechanics, optics, electronics, chemical, biomedical, catalysis, environmental, energy, sensing, security, defense, etc. Integration will need to be across material sets (0D, 1D, 2D, 3D, hierarchical nanoparticles, etc.), across length-scales (molecular to nano to micro to meso to macro), and across function (mechanical, electrical, optical, chemical, biological, thermal, etc.) and across processes (top-down, bottom-up). Integration will involve the study and implementation of hybrid manufacturing and assembly processes and methods. The research will be driven by the need to understand and establish, among others, design rules for integrated systems, manufacturing and integration process and control models, and measurement science and technology. The desired outcome will be a nano-enabled integrated system that combines many different functions together to work as one entity and that is made up of component subsystems that are designed to perform in a unified manner.

The SNM-IS solicitation seeks proposals that investigate novel scalable nanomanufacturing and integration methods for nano-enabled integrated systems with a clear commercial relevance. Proposals should consider addressing key aspects of the nanomanufacturing value chain comprised of nano-scale building-blocks → complex nanomaterials and nanostructures → functional components and devices → integrated sub-systems and systems:

- **Novel nanomanufacturing processes and integration strategies for large-area or continuous manufacturing or customized manufacturing of nano-scale materials and structures and their assembly into larger-scale components and devices and the integration of the components and devices into higher order structures, subsystems and systems;**
- **Fundamental scientific research in key, well-defined technical areas that are compellingly justified as approaches to overcome critical scientific and engineering barriers to nanomanufacturing scale-up, customized nanomanufacturing and multi-scale integration; and**
- **Design principles for production systems leading to nanomanufacturing tools, and platforms; identification of manipulation and control methodologies, and metrology, instrumentation, and standards needed for process monitoring and control and to assess quality and yield; determination of process models and simulations to guide processing and integration; identification of environmental and energy footprints, as applicable.**

Competitive proposals will incorporate the following three elements in their research plans:

1. A persuasive case that the nano-enabled integrated system to be manufactured has or is likely to have sufficient demand to justify eventual scale-up or meet demands for low-volume specialty materials or device systems;
2. A clearly identified set of research challenges requiring science and engineering solutions that must be addressed to enable the realization of integrated systems for the cost-effective manufacture of high quality nano-enabled products in large quantities or low-volume specialty products; and
3. A compelling research plan with clear objectives and approaches to overcome the identified research challenges. This may include environmentally benign approaches and life-cycle considerations.

These elements should be carefully explained and justified in proposals, since both the scientific novelty and the feasibility of the methods being researched will be important evaluation factors.

The SNM-IS solicitation is NOT seeking research proposals in large-scale manufacturing of single component nanomaterials and nanostructures. Novel ideas in novel nanomanufacturing processes and scale-up may be sent to the core Nanomanufacturing (NM) Program.

Competitive proposals are expected to address the training and education of students in nanomanufacturing, system integration and related areas. Since Scalable Nanomanufacturing for Integrated Systems research will involve addressing multiple scientific and engineering challenges in the design and manufacture of complex nano-enabled integrated systems, an inter-disciplinary approach is strongly encouraged. Disciplines could range from the physical sciences (physics, chemistry, biology, materials science and others) to engineering (materials, mechanical, electrical, chemical, biomedical, industrial and others) and could include mathematics and computer science. While not required, collaborative activities with industrial or small business companies (e.g., through the GOALI program) are welcome and collaborations in which industrial partners develop industrially relevant test-beds where university and company researchers can experiment and interact are encouraged. It is advisable that such firms be consulted early in the proposal preparation process and that their intellectual contributions be clearly explained in the proposal.

Other research and education projects in nanoscale science and engineering will continue to be supported in the appropriate programs and divisions.

Please see requirements for submitting proposals for collaborations; a single proposal with sub-contracts must be submitted for collaborations and the submission of separate proposals from multiple investigators for collaborative projects ('collaborative proposals') is not allowed.

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.

- Khershed Cooper, telephone: (703) 292-7017, email: khcooper@nsf.gov
- Nora F. Savage, telephone: (703) 292-7949, email: nosavage@nsf.gov
- Nadia El-Masry, telephone: (703) 292-8153, email: nelmasry@nsf.gov
- Diana Farkas, telephone: (703) 292-7576, email: dfarkas@nsf.gov
- Tania Paskova, telephone: (703) 292-2264, email: tpaskova@nsf.gov
- Melur (Ram) Ramasubramanian, telephone: (703) 292-7107, email: mramasub@nsf.gov
- Rajesh Mehta, telephone: (703) 292-2174, email: rmehta@nsf.gov

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

- 47.041 --- Engineering
- 47.049 --- Mathematical and Physical Sciences

Award Information

Anticipated Type of Award: Standard Grant or Continuing Grant

Estimated Number of Awards: 5 to 8

Anticipated Funding Amount: $5,000,000

pending the availability of funds

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:

Principal Investigators must be at the faculty level or equivalent.

Limit on Number of Proposals per Organization: 1

An academic institution – a university, or a campus in a multi-campus university -- may submit no more than one (1) proposal on which it is the lead organization in response to this solicitation. Potential PIs are advised to contact their institutional office of research regarding processes used to select proposals for submission. The same organization may be a collaborative partner in any number of other multi-organization group proposals in which it is not the lead. A proposal involving more than one organization must be submitted as a single proposal in which a single award is requested, with the managing principal investigator from the lead organization and subawards administered by the lead organization to any other participating organizations.

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

There are no restrictions or limits.

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, Part I: Grant Proposal Guide (GPG) Guidelines apply. The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg.
  - 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:**

  Not Applicable

C. Due Dates

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

  January 13, 2017

Proposal Review Information Criteria

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

Award Conditions:

Standard NSF award conditions apply.

Reporting Requirements:

Standard NSF reporting requirements apply.

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I. INTRODUCTION

A length of one nanometer (one billionth of a meter) approximately defines both the minimum feature size of the smallest human-made structures and the dimension of small molecules from which living things are assembled. Nanoscale materials and structures are designed to have novel physical and chemical properties that derive from their intermediate scale, where unique properties between atomic and bulk behaviors can be accessed and controlled. While many potentially technologically interesting nanomaterials and nanostructures have been identified, these often have been produced using slow and expensive methods with little potential for economical production at commercial scale. The assembly of nanomaterials and nanostructures into components and devices is usually done batch-wise, which further reduces the speed of production. However, progress has been made in component assembly using continuous and other high-throughput processes. One area where significant advances are needed is in multi-scale integration of nanostructures, nanocomponents and nanodevices into subsystems and systems. There is a need for economical methods for making nano-enabled integrated systems. These may be created by combining various manufacturing and assembly techniques, including but not limited to combinations of molecular, self- and directed-assembly and top-down miniaturization, bio-assembly, networking at the nanoscale and multi-scale and hierarchical architectures, robotics on surfaces, nanomodular materials and systems by design, chemo-mechanical processing of molecular assemblies, and quantum interactions. These are just a few examples of processes among many others that may be studied towards the realization of nano-enabled integrated systems. Research may also be directed to the study of processes for the realization of specialty, customized integrated systems, which are necessarily low-volume. Another challenge to consider is economical nanomanufacturing and integration with zero or near zero waste production.

II. PROGRAM DESCRIPTION

The SNM-IS solicitation is seeking high-risk/high-reward research and education proposals. Its focus is on challenges in scalable nanomanufacturing for integrated systems and societal and educational issues associated with continuing advances in the nanomanufacturing research field and the ensuing increasing use of nanoscale materials, devices and systems. **All proposals**

should clearly state what technical roadblocks to integration and scale-up exist and what new approach or approaches will be investigated to overcome those roadblocks. The scientific and engineering barriers to commercialization, in terms of production rate, throughput, quality, reproducibility, yield, efficiency, sustainability, mass customization and cost should be addressed in the proposal.

In preparation of the proposal, the research team should consider one (or more) of the following elements of Scalable Nanomanufacturing for Integrated Systems:

- ***Novel nanomanufacturing processes and integration strategies for large-area or continuous manufacturing or customized manufacturing of nano-scale materials and structures and their assembly into larger-scale components and devices and the integration of the components and devices into higher order structures, subsystems and systems.***

Processes could be top-down (deposition, lithography) or bottom-up (directed- and self-assembly) or a combination of the two. Deposition processes could be vapor- or solution-based or any other. Lithography processes could be tip-, directed energy-, print- or imprint-based or any other. Assembly processes could be spontaneous or directed via physical, electrostatic, magnetic, acoustic, chemical, biological, thermal or any other means. Research on creating nanostructures that can be easily assembled into large-scale nanosystems and systems of such nanosystems is sought. It is anticipated that such systems will comprise of discrete elements that are differentiable in composition, structure, dimension, and/or geometry. It is further anticipated that such desired integrated systems could be broken down into a finite number of interacting or interdependent subsystems and components with individually-defined functions. The proposed methodologies should lead to the fabrication of complex heterogeneous nanostructures and components, which are integrated into higher order devices and systems. The potential for high-volume production of industrially-relevant nano-enabled systems or low-volume production of specialized systems should be demonstrated. Research in computation, modeling and simulation, coupled with bench-scale and high throughput experimentation in support of the scale-up and integration of nanomanufacturing processes is sought. Projects identifying specific technological roadblocks and proposing academic-industry research partnerships to overcome them are particularly encouraged. These may include research efforts inspired by promising novel nanotechnologies, fabrication approaches and tools recently demonstrated in industry or academia that likely have wider applicability. Examples of such approaches include large area or multi-wafer nanofabrication, continuous reactive processing, continuous roll-to-roll processing, massively-parallel processing, layer-by-layer processing, self-organizing structuring, and other high-throughput methods as well as methods for low-volume production of customized nano-enabled integrated systems such as additive manufacturing.

- ***Fundamental scientific research in key, well-defined technical areas that are compellingly justified as approaches to overcome critical scientific and engineering barriers to nanomanufacturing scale-up, customized nanomanufacturing and multi-scale integration; and.***

Approaches for the scale-up and integration of both emergent and more well-established materials synthesis and processing methods are desired. For example, proposals that include new theoretical developments related to nanoscale materials, physics, chemistry or biology; ideas for creating mathematical models for manufacturability; experimental and computational methodologies for retaining nanoscale properties in materials and function in nano-enabled systems after scale-up or as customized systems; harnessing of interfaces across dimensional scales; and exploration of production-scale assembly approaches for device fabrication and system integration are welcome. High production rate, throughput, quality, reproducibility and yield are all required for commercial viability. Some emerging fields of application appear to be particularly well suited for scale-up or mass customization. In more established areas, researchers should clearly state what roadblocks to scale-up and system integration exist and what new approach or approaches will be investigated to overcome these roadblocks.

- ***Design principles for production systems leading to nanomanufacturing tools, and platforms; identification of manipulation and control methodologies, and metrology, instrumentation, and standards needed for process monitoring and control and to assess quality and yield; determination of process models and simulations to guide processing and integration; identification of environmental and energy footprints, as applicable.***

Research is encouraged on design principles, architectures and construction methods for nanoscale measurement and processing tools and platforms. Research in this area anticipates instrumentation with integrated and/or stand-alone capabilities for the nanometer-scale resolution metrology of three-dimensional objects, new tools for sensing, assembling, processing, manipulating, manufacturing and integrating across length scales, across material sets, and across functions; new sensing modalities and algorithms for controlling and testing nanostructures and devices, and design automation tools for assembling devices and systems of large numbers of heterogeneous nanocomponents. This research should be strongly grounded in fundamental understanding of nanoscale processes and system design rules, and should integrate novel concepts for measurement, high-rate synthesis and processing, multi-scale integration, and scale-up of nanoscale processing methods that derive from such understanding. Key factors in the progression to large-scale nanomanufacturing of integrated systems and low-volume manufacturing of specialized systems involve standardization and the development of measurement, control and quality monitoring methods. Towards that end, approaches are sought for reliable, high-speed, high-resolution on-line or off-line metrology, diagnostics, and adaptive (real-time) control methods and the process simulation and design methods needed in nanomanufacturing and integration.

In addition, proposals should address technological, societal, educational, sustainability and outreach implications in context of the SNM-IS solicitation. NSF has a strong interest in developing the infrastructure for nanoscale science and engineering. Accordingly, all proposals should address integration of research and education, for example, by including course development appropriate to the nature of the project. Collaborations between research universities and community colleges to provide curricula and research experiences to educate the future nanomanufacturing workforce are particularly encouraged.

NSF does not normally support technical assistance, pilot plant efforts, research requiring security classification, or the development of products for commercial marketing or market research for a particular project or invention. Other research and education projects in nanoscale science and engineering will continue to be supported in the relevant programs, divisions and directorates.

Principal Investigators should ensure that their proposed project does not substantially overlap with ongoing federally-funded research. Proposals submitted in response to this solicitation may be shared by NSF with other federal agencies, including (but not limited to) the National Aeronautics and Space Administration, National Institute of Standards and Technology, Department of Energy, National Institutes of Health, Environmental Protection Agency, Defense Advanced Research Projects Agency, Air Force Office of Scientific Research, Army Research Office, Office of Naval Research, and the Intelligence Community. Reviews, including panel summaries, if applicable, may also be shared. The reasons for sharing these proposals and reviews include potential co-funding as well as avoiding duplication of federal funding for a particular research project. If the PI or awardee organization does not wish the proposal to be shared with a particular federal agency or agencies for funding purposes, they should provide a Single Copy Document with the proposal stating which federal funding agencies should be excluded. No explanations for exclusion are required.

III. AWARD INFORMATION

Anticipated Type of Award: Continuing Grant or Standard Grant.

Estimated Number of Awards: 5-8.

Awards will be in the range of **$250,000-$375,000 per year for four years**, depending on the scope of the work proposed. Grants may be awarded in a variety of sizes and durations. The total request for NSF funding for each project, for all investigators and all organizations, **may not exceed $1,500,000**. NSF expects to fund approximately 5-8 awards in FY 2017, depending on the quality of submissions and pending the availability of funds. Anticipated date of awards: July 2017.

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:

Principal Investigators must be at the faculty level or equivalent.

Limit on Number of Proposals per Organization: 1

An academic institution – a university, or a campus in a multi-campus university -- may submit no more than one (1) proposal on which it is the lead organization in response to this solicitation. Potential PIs are advised to contact their institutional office of research regarding processes used to select proposals for submission. The same organization may be a collaborative partner in any number of other multi-organization group proposals in which it is not the lead. A proposal involving more than one organization must be submitted as a single proposal in which a single award is requested, with the managing principal investigator from the lead organization and subawards administered by the lead organization to any other participating organizations.

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

There are no restrictions or limits.

Additional Eligibility Info:

Proposals may be submitted by a single organization or a group of organizations consisting of a lead organization in partnership with one or more partner organizations. Only U.S. academic institutions with significant research and degree-granting education programs in disciplines normally supported by NSF are eligible to be the lead organization. Principal investigators are encouraged to form collaborations among researchers. However no funds will be provided to private and public sector organizations, government laboratories, or scientists and engineers at foreign organizations. At least three PIs and co-PIs, all with funded time committed in the budget, must be listed on the cover page and on the budget page of the proposal. The maximum number of PIs and co-PIs is five; other participants may be listed in the project summary and on the budget pages.

Collaborations between university and industry researchers using the approach of the Grant Opportunities for Academic Liaison with Industry (GOALI) program are encouraged. *Please see section IX. Other Information about GOALI.* Primary support for foreign participants or activities, or both must be secured through their own national sources. For foreign participants, the U.S. organization may provide funds under participant support costs for travel and per diem for visits to the U.S. organization as consistent with applicable international agreements. No NSF funds may go directly to foreign organizations. For this solicitation, funds for salaries and research expenses of staff of for-profit companies, national laboratories, state agencies, and non-NSF Federally Funded Research and Development Centers (FFRDC) may not be requested. However, it is appropriate for students supported by the award to work on a funded project at a for-profit company, an FFRDC or another comparable site and for the award to support research expenses incurred when scientists from such entities work at university sites. Federal employees may not receive salaries or in other ways augment their agency's appropriation through grants made by this solicitation, and no funds for equipment at for-profit companies, FFRDCs, or other comparable entities are allowed.

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 Grant Proposal Guide (GPG). The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg. Paper copies of the GPG 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.

See Chapter II.C.2 of the GPG 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 GPG instructions.

The standard Grant Proposal Guide or NSF Grants.gov Application Guide instructions for proposal preparation apply, with the following modifications.

Collaborative research activities should be described and submitted in a single proposal in which a single award is requested, with subawards administered by the lead organization to any other participating organizations (see GPG Chapter II.D.5). This solicitation encourages team approaches. Budgets for any subawards to different organizations must be included.

Cover Page:

- FastLane Users: Proposers must identify this program solicitation number in the program announcement/solicitation block on the Cover Sheet and select “Scalable Nanomanufacturing” from the FastLane org. unit pull-down list. The project title must begin with **"SNM:"**
- Grants.gov Users: The program solicitation number will be pre-populated by Grants.gov on the NSF Grant Application Cover Page. In Field 2, Unit of Consideration, enter 07030000 for the Division Code and 025Y for the Program Code. The project title must begin with **"SNM:"**

Project Summary:

Each proposal must contain a summary of the proposed project not more than one page in length. The Project Summary consists of an overview, a statement on the intellectual merit of the proposed activity, and a statement on the broader impacts of the proposed activity, each clearly labeled. Proposers must address specific barriers to manufacturability at large-scale or low-volume mass customization for a nano-based integrated system, indicate proposed process and integration methods to overcome these barriers, target specific integrated systems to demonstrate feasibility, and indicate the potential technological impact. The nature of the scalable nanomanufacturing and integration techniques, and the type of integrated system/s and potential applications will be used to assist in assignment of the proposal to the most appropriate review panel.

Project Description:

Besides the fundamental research objectives and approaches to overcome the stated scalable nanomanufacturing and system-integration challenges, the project description should include a discussion of environmental, societal and education implications of the project and a management plan for coordinating project activities and attaining key project milestones. The proposal should describe the roles to be played by the participating organizations, the responsibilities of the managing PI, the activities of associated partners, and arrangements for the networking, exchange, and dissemination of data and the translation of results to organizations with experience in scale-up and integration to commercial scale. The managing PI must be from the lead organization. Details on the education, training, and any outreach activities planned as part of the project should be included. Opportunities for students to obtain novel research or educational experiences, any specific training activities or workshops should be considered.

The project description is limited to 15 pages and proposals that exceed the page limitation will be returned without review.

B. Budgetary Information

Cost Sharing:

Inclusion of voluntary committed cost sharing is prohibited.

C. Due Dates

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

  January 13, 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 the GPG as 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. (GPG 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 GPG 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

In addition, the following criteria will be used:

1. Potential for significant contributions to the advancement of the field of nanomanufacturing. Examples include: Novel scalable processes and techniques and integration strategies for high volume nanomanufacturing of integrated systems and manufacturing of low-volume specialty nano-enabled systems; New strategies for integration of nanomaterials and nanostructures into large-scale functional components and devices and integration of these into higher-order architectures and systems; Fundamental scientific research in well-defined technical areas that are compellingly justified as approaches to overcome critical barriers to scale-up and system integration; and/or, Design principles for production systems leading to nanomanufacturing and system integration platforms, identification of metrology, instrumentation, standards and control methodologies needed for process control and to assess quality and yield.
2. Uniqueness and importance of the impacts of the project as they relate to nanomanufacturing and system integration. For example, the societal, environmental and economic implications of the large-scale production and specialty product manufacture and use of integrated systems; and/or the added value to nanomanufacturing education.
3. Strength of the team and their interactions evident through planned collaborations, especially, industrial collaborations; appropriateness and likely effectiveness of those collaborations; quality of the collaborations, not on the number of collaborators; degree of inter-disciplinary synergy; and likely effectiveness of the management plan.

B. Review and Selection Process

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

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 *Award & Administration Guide* (AAG) Chapter II, available electronically on the NSF Website at http://www.nsf.gov/publications/pub_summ.jsp?ods_key=aag.

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.

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:

- Khershed Cooper, telephone: (703) 292-7017, email: khcooper@nsf.gov

- Nora F. Savage, telephone: (703) 292-7949, email: nosavage@nsf.gov
- Nadia El-Masry, telephone: (703) 292-8153, email: nelmasry@nsf.gov
- Diana Farkas, telephone: (703) 292-7576, email: dfarkas@nsf.gov
- Tania Paskova, telephone: (703) 292-2264, email: tpaskova@nsf.gov
- Melur (Ram) Ramasubramanian, telephone: (703) 292-7107, email: mramasub@nsf.gov
- Rajesh Mehta, telephone: (703) 292-2174, email: rmehta@nsf.gov

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.

For questions related to the use of FastLane, contact: telephone: 1-800-673-6188, email: fastlane@nsf.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.

Grant Opportunities for Academic Liasion with Industry (GOALI), http://www.nsf.gov/pubs/2016/nsf16099/nsf16099.jsp. GOALI aims to synergize university-industry partnerships by making funds available to support an eclectic mix of industry-university linkages. Special interest is focused on affording the opportunity for:

- Interdisciplinary university-industry teams to conduct long-term research projects;
- Faculty, postdoctoral fellows, and students to conduct research and gain experience with production processes in an industrial setting; and
- Industrial scientists and engineers to bring industry's perspective and integrative skills to academe.

This solicitation, previous program solicitations, and additional information concerning related activities such as workshops and publications, including **"The National Nanotechnology Initiative - Supplement to the President's FY 2017 Budget (2016)"** prepared by the National Science and Technology Council, are available on-line at https://www.nsf.gov/nano and http://www.nano.gov/.

To accelerate nanotechnology development in support of the President's priorities and innovation strategy, in accordance with the recommendations of the President's Council of Advisors on Science and technology (PCAST), NNI member agencies have identified areas ripe for significant advances through close and targeted program-level interagency collaboration. The resulting Nanotechnology Signature Initiatives include **"Sustainable Nanomanufacturing," "Nanoelectronics for 2020 and Beyond," "Nanotechnology for Solar Energy Collection and Conversion", "Nanotechnology for Sensors", "Nanotechnology Knowledge Infrastructure" and "Water Sustainability through Nanotechnology".** All six publications are available at http://www.nano.gov/signatureinitiatives). This program solicitation is a partial contribution to these NNI, National Science and Technology Council, initiatives.

The PCAST report, **"The National Nanotechnology Initiative 2010: Third Assessment and Recommendations of the National Nanotechnology Advisory Panel,"** is available at http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-nano-report.pdf.

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 provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See Grant Proposal Guide Chapter II, Section D.2 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:

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