



FY 2016

**Small Business Innovation Research
(SBIR) Program**

Federal Funding Opportunity (FFO)

ANNOUNCEMENT

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**U.S. DEPARTMENT OF COMMERCE
National Institute of Standards and Technology**

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<http://www.nist.gov/sbir>

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**US DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
FY 2016 SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM
FEDERAL FUNDING OPPORTUNITY (FFO)**

1.0 PROGRAM DESCRIPTION AND FEDERAL AWARD INFORMATION

1.01 Introduction

The National Institute of Standards and Technology (NIST) invites small businesses to submit Phase I research applications under this Federal Funding Opportunity (FFO). Firms with strong research capabilities in any of the areas listed in Section 9 of this FFO are encouraged to participate. Applications not addressing one of the subtopics in Section 9 are not responsive to this FFO.

Only FY 2016 Phase I applications may be submitted in response to this FFO. FY 2017 Phase II applications are currently not being accepted. Rather, NIST will publish an FFO approximately 30 days prior to the end of the FY 2016 Phase I performance period to request FY 2017 Phase II applications. The FFO will provide the instructions to prepare an FY 2017 Phase II application and provide the closing date for FY 2017 Phase II applications. Only FY 2016 Phase I awardees will be eligible to submit FY 2017 Phase II applications.

The Small Business Innovation Research (SBIR) program was originally established in 1982 by the Small Business Innovation Development Act (P.L. 97-219), codified at 15 U.S.C. § 638. It was then expanded and extended by the Small Business Research and Development (R&D) Enhancement Act of 1992 (P.L. 102-564), and received subsequent reauthorization and extensions that include Public Law 112-81, extending SBIR through September 30, 2017.

Eleven federal agencies implement SBIR by setting aside a portion of their extramural research and development budget each year to fund research applications from small science and technology-based firms. The statutory purpose of the SBIR Program is to strengthen the role of innovative small business concerns (SBCs) in Federally-funded research or research and development (R/R&D). Specific program goals are to: (1) stimulate technological innovation; (2) use small business to meet Federal R/R&D needs; (3) foster and encourage participation by socially and economically disadvantaged small businesses and by women-owned small businesses in technological innovation; and (4) increase private sector commercialization of innovations derived from Federal R/R&D, thereby increasing competition, productivity and economic growth.

The NIST FY 2016 SBIR program identifies and solicits applications in topics that fall within NIST's mission and allow collaboration between NIST scientists and the SBIR awardees whenever possible. In order to ensure a greater strategic alignment between the SBIR

program and NIST's laboratory research program, the SBIR topics are the priority areas identified in the NIST Programmatic Plan FY 2016-2018 available at: <http://www.nist.gov/director/planning/planning.cfm>.

Subtopics set forth in Section 9 of this FFO are intended to cultivate private sector innovation and foster and encourage participation by minority and disadvantaged persons in technological innovation.

In developing topics and subtopics and when reviewing applications, NIST gives high priority to small business concerns that participate in or conduct energy efficiency or renewable energy system R&D projects, consistent with Executive Order (EO) 13329 (<http://www.gpo.gov/fdsys/pkg/FR-2004-02-26/pdf/04-4436.pdf>) "Encouraging Innovation in Manufacturing," the Energy Independence and Security Act of 2007 (P.L. 110-140 § 1203(e), codified at 15 U.S.C. § 638(z)), and the Small Business Administration (SBA) SBIR Policy Directive, § 9, found at http://www.sbir.gov/sites/default/files/sbir_pd_with_1-8-14_amendments_2-24-14.pdf.

Any SBIR award addressing a subtopic that includes a background invention will, as necessary, be granted a non-exclusive research license to use those NIST-owned patented inventions. No commercialization license to make, use or sell products or services incorporating the NIST background invention will be granted until an SBIR awardee applies for, negotiates and receives a research license and complete its Phase II award. All awardees with agreements for technologies that identify specific NIST background inventions will be given the opportunity to negotiate a non-exclusive commercialization license to such inventions as provided in the Federal patent licensing regulations, set forth in 37 C.F.R. Part 404.

Once awarded and, where necessary, granted a license to use NIST technology, it is the goal of this program that the SBIR awardee will be positioned to create and add its own innovation and develop a commercially viable product based on the NIST developed technology.

1.02 Three-Phase Program

The SBIR statute (15 U.S.C. § 638) requires the Department of Commerce (DoC) to establish a three-phase SBIR program by reserving a percentage of its extramural R&D budget to be awarded to small business concerns for innovation research. SBIR policy is provided by the SBA through the [SBIR Policy Directive](#).

The funding vehicles for NIST's SBIR program in both Phase I and Phase II are cooperative agreements. NIST's authority to implement its SBIR program through cooperative agreements is 15 U.S.C. § 272(b)(4). NIST programmatic authorities for the subtopics listed in this FFO are found at 15 U.S.C. § 272(b) and (c). The nature of NIST's "substantial involvement" will generally be collaboration with the awardees in carrying out the scope of

work. Additional forms of substantial involvement that may arise are described in Chapter 5.C of the DoC Grants and Cooperative Agreements Manual, which is available at <http://go.usa.gov/SNJd>. Please note the DoC Grants and Cooperative Agreements Manual is expected to be updated after publication of this funding announcement but prior to issuance of any Phase I awards. Refer to Section 1.05 of this FFO, Contact with NIST, Grant Rules and Regulations, if you seek the information at this link and it is no longer working or you need more information. Grants and agreements administrative requirements set forth at 2 C.F.R. Part 200 will apply to NIST SBIR awards.

1.02.01 Phase I - Feasibility Research

The purpose of Phase I is for NIST to determine the technical feasibility of the research, preliminary commercialization potential of the proposed effort, and the quality of the awardee's performance. Therefore, the application should concentrate on describing research that will significantly contribute to proving the feasibility of the proposed Phase II research, a prerequisite to receiving further support in Phase II.

1.02.02 Phase II - Research and Development

All Phase I awardees under this FFO will be given the opportunity to submit a Phase II application following completion of Phase I. Instructions for Phase II application preparation and submission requirements will be published in an FFO approximately 30 days prior to the end of the FY 2016 Phase I performance period to request FY 2017 Phase II applications.

In Phase II, work from Phase I that exhibits potential for commercial application is further developed. Phase II is the R&D or prototype development phase. To apply for a Phase II award, each Phase I awardee will be required to submit a comprehensive application outlining the research. Each NIST Phase II award is for up to \$300,000 and up to a 24 month period of performance. One year after completing the Phase II R&D activity, the awardee shall be required to report on its commercialization activities.

1.02.03 Phase III - Commercialization

Phase III refers to work that derives from, extends, or completes an effort made under prior SBIR funding agreements, but is funded by sources other than the SBIR Program. Phase III work is typically oriented towards commercialization of SBIR research or technology and may be for products, production, services, R/R&D or a combination thereof.

1.02.04 Commercialization Readiness Pilot Program

As allowed in Section 5123 of the SBIR/STTR Reauthorization Act of 2011, Division E of Pub. L. 112-81, NIST has received authorization to establish a Commercialization Readiness Pilot Program (CRPP). NIST may provide supplemental funding (up to an additional ten percent of the Phase II award) to selected awardees after completion of Phase II. The funding would be

used to further develop Phase II technologies, to support advancement toward Phase III, and to increase the likelihood of commercialization. NIST is under no obligation to make any CRPP awards.

1.03 SBIR Applicant Eligibility and Limitations

1.03.01 Applicant Qualifications

Each applicant for both Phase I and Phase II must qualify as a small business concern for R/R&D purposes, as defined in Section 1.06 of this FFO, at the time of award. In addition, the primary employment of the principal investigator must be with the small business at the time of the award and during the conduct of the proposed research. Primary employment means that more than one-half of the principal investigator's time is spent working with the small business. Primary employment with a small business precludes full-time employment with another organization. Occasionally, deviations from this requirement may occur, which must be approved in writing by the NIST Grants Officer after consultation with the SBIR Program Manager. Further, a small business may only replace the principal investigator on an SBIR Phase I or Phase II award if the NIST Grants Officer provides prior written approval. Personnel obtained through a Professional Employer Organization or other similar personnel leasing company may be considered employees of the awardee.

For both Phase I and Phase II, the R/R&D work must be performed in the United States. However, based on a rare and unique circumstance, agencies may approve a particular portion of the R/R&D work to be performed or obtained in a country outside of the United States, for example, if a supply or material or other item or project requirement is not available in the United States. The NIST Grants Officer must approve each such specific condition in writing.

NIST has elected to not use the authority that would allow venture capital operating companies (VCOs), hedge funds or private equity firms to participate in the SBIR Program. Therefore, applications in which work would be performed by VCOs will not be considered for award.

For Phase I, a minimum of two-thirds of the research and/or analytical effort must be performed by the awardee. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-third of the total award. For Phase II, a minimum of one-half of the research and/or analytical effort must be performed by the awardee. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-half of the total award.

Each Phase I and Phase II applicant will be required to provide certain information via www.SBIR.gov as well as other information required by the [SBIR Policy Directive](#) (see Appendices V-VI). Each SBC applying for an award is required to update the appropriate

information in the SBA Tech-Net database on SBIR.gov for any of its existing and prior Phase II awards.

Applicants may not participate in the selection of any topic or subtopic nor in the review of applications.

The statement of work of an SBIR award awarded under this FFO cannot overlap with the statement of work of an existing NIST Cooperative Research and Development Agreement (CRADA) with the awardee. NIST will consider the issue of any potential overlap on a case-by-case basis.

1.03.02 Company Registry Requirements

SBA maintains and manages a Company Registry at <http://www.sbir.gov/registration> to track ownership and affiliation requirements for all companies applying to the SBIR Program. **Each Phase I and Phase II applicant must register in the Company Registry prior to submitting an application. The applicant must save its information from the registration in a .pdf document and append this document to SF-424 form as described in Section 8.01.(9) of this FFO.** All applicants are required to report and/or update their registration information in the SBA Company Registry prior to each SBIR application submission or if any information changes prior to an award.

1.03.03 Performance Benchmark Ratings Requirements

All Phase I applicants with a current Small Business Administration (SBA) assessment of their *Phase I to Phase II Transition Rate* must at the time of the award have satisfied the requirements of that Performance Benchmark to be eligible for a new Phase I award. NIST will not consider proposals from firms that are currently ineligible for Phase I awards as a result of failing to meet the benchmark rate at the last assessment.

The *Phase I to Phase II Transition Rate* requirement applies only to SBIR Phase I applicants that have received more than 20 (21 or more) Phase I awards over the past 5 fiscal years (excluding the most recent year). For these applicants, the ratio of the number of Phase II awards (awarded during the past 5 fiscal years) to the number of Phase I awards (awarded during the past 5 years excluding the most recent year) must be at least 0.25. For the purposes of this FFO, the applicable five fiscal year period is fiscal year 2010 to fiscal year 2014. On June 1st of each year, the SBA assesses the Performance Benchmark rates for all applicable SBIR and Small Business Technology Transfer (STTR) awardees in the Company Registry. STTR is another program that expands funding opportunities in the federal innovation research and development arena. See <https://www.sbir.gov/about/about-sttr>. Performance Benchmark rates are based on a company's total SBIR/STTR awards, across all the participating agencies. Companies that fail to meet the Performance Benchmark requirements are not eligible to receive a Phase I award for a period of one year from the

assessment: from June 1st through May 31st. Note that this does not affect a company's eligibility for Phase II or Phase III awards.

SBA sends three notifications each year to companies affected by the benchmark performance requirements:

February 1st – SBA identifies and notifies via email all companies that, on that date, have won enough past awards to be subject to the benchmark requirements. (For FY2015, this email was sent on March 10, 2015).

April 1st – SBA runs a preliminary assessment to determine which companies appear to be failing a benchmark given the data in the system on that date. SBA sends a Warning Notice to these companies so that they can review the award in the Company Registry (SBIR.gov) and update as needed.

June 1st – SBA identifies companies that fail a benchmark and notifies them that they may not be eligible to receive a new Phase I award for a period of one year.

NOTE: Before responding to this FFO, all applicants should verify their *Transition Rate* eligibility for Phase I awards. When logged in to the Company Registry at <https://www.sbir.gov/registration>, awardees can view their last assessed *Transition Rate* by clicking on the “Performance Benchmark” side-bar. These company-specific rates appear under the heading “At Last Assessment.” A thumbs-up/thumbs-down indicator shows whether or not the company passed the benchmark rates at the last assessment. If at any time, a company believes the award information on SBIR.gov is not correct, it should notify SBA using the *dispute* link provided. If a company's dispute of the data used for the rates is under review, it will see “TBD” under the “At Last Assessment” heading. Companies with less than the threshold number of awards (21 Phase I awards for the Transition Rate a) will see “N/A” displayed because the requirement did not apply to them.

Under the heading “Current (On-Going)”, the page displays a running calculation of the benchmark rates using the next years' time periods (each period moved up by one year) and current data in the system. Companies should monitor these rates to anticipate their standing for each upcoming June 1 Assessment. Prior to proposal preparation, all applicants to this FFO that have received more than 20 Phase I awards across all federal SBIR/STTR agencies over the past five (5) years should verify that their company will not have a failing status on the *Transition Rate* Benchmark at the time of award.

Performance Benchmarks: (General information on the Performance Benchmark requirements is available at <https://www.sbir.gov/performance-benchmarks>.)

1.04 Contact with NIST

In the interest of competitive fairness, all oral or written communication with NIST during the Phase I open FFO period - with the exception of the public Question and Answer site located at <http://www.nist.gov/sbir>, is prohibited. Questions may be submitted through the NIST SBIR website, and all responses will be publicly, though

anonymously, posted on the web site. Questions and answers will not be accepted through nor posted on Grants.gov.

Applicants may also contact the NIST Hollings Manufacturing Extension Partnership (MEP) to be directed to Centers for technical assistance with application preparation. More information on obtaining technical assistance from MEP Centers for application preparation can be found in Section 5.12 of this FFO.

For programmatic, electronic submission, or grants questions, please contact the appropriate individual:

Subject Area	Point of Contact
Programmatic Questions	Mary Clague Phone: (301) 975-4188 Fax: (301) 975-3482 E-mail: mary.clague@nist.gov or J'aime Maynard Phone: (301) 975-8408 E-mail: jmaynard@nist.gov
Electronic Application Submission through Grants.gov	Christopher Hunton Phone: (301) 975-5718 Fax: (301) 975-8884 E-mail: grants@nist.gov or Grants.gov Phone: 800-518-4726 E-mail: support@grants.gov
Grant Rules and Regulations	Robin Bunch Phone: (301) 975-8006 Fax: (301) 975-6368 E-mail: robin.bunch@nist.gov

1.05 Definitions

Except as specifically noted by citation or reference, all definitions below are excerpted from the SBA SBIR Policy Directive, available at http://sbir.gov/sites/default/files/sbir_pd_with_1-8-14_amendments_2-24-14.pdf.

Applicant – The organizational entity that qualifies as a Small Business Concern (SBC) at all pertinent times and that submits a contract proposal or a grant application for a funding agreement under the SBIR Program.

Awardee – The organizational entity that receives an SBIR Phase I, Phase II or Phase III award.

Commercialization - The process of developing products, processes, technologies, or services and the production and delivery (whether by the originating party or others) of the products, processes, technologies, or services for sale to or use by the Federal government or commercial markets.

Cooperative Agreement - A financial assistance mechanism used when substantial Federal programmatic involvement with the awardee during performance is anticipated by the issuing agency. The Cooperative Agreement contains the responsibilities and respective obligations of the parties.

Contract – A mutually binding legal relationship obligating the seller to furnish equipment, goods or services and the buyer to pay for them.

Essentially Equivalent Work - Work that is substantially the same research, which is proposed for funding in more than one contract proposal or grant application submitted to the same Federal agency or submitted to two or more different Federal agencies for review and funding consideration; or work where a specific research objective and the research design for accomplishing the objective are the same or closely related to another proposal or award, regardless of the funding source.

Feasibility - The practical extent to which a project can be performed successfully.

Funding Agreement - Any contract, grant, or cooperative agreement entered into between any Federal agency and any SBC for the performance of experimental, developmental, or research work, including products or services, funded in whole or in part by the Federal Government.

Joint Venture – See 13 C.F.R. § 121.103(h).

Research or Research and Development (R/R&D) - Any activity that is:

- (1) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied;
- (2) a systematic study directed specifically toward applying new knowledge to meet a recognized need; or
- (3) a systematic application of knowledge toward the production of useful materials, devices, services, or methods, and includes design, development, and improvement of

prototypes and new processes to meet specific requirements.

SBIR Technical Data - All data generated during the performance of an SBIR award.

SBIR Technical Data Rights - The rights an SBIR awardee obtains in data generated during the performance of any SBIR Phase I, Phase II, or Phase III award that an awardee delivers to the Government during or upon completion of a Federally-funded project, and to which the Government receives a license.

Small Business Concern (SBC) – A concern that meets the requirements set forth in 13 C.F.R. § 121.702 (available at <http://www.gpo.gov/fdsys/granule/CFR-2011-title13-vol1.CFR-2011-title13-vol1-sec121-702>).

Socially and Economically Disadvantaged SBC (SDB) - See 13 C.F.R. Part 124, Subpart B.

Socially and Economically Disadvantaged Individual - See 13 C.F.R. §§ 124.103 and 124.104.

Subaward – See 2 C.F.R. § 200.92.

Women-Owned Small Business (WOSB) - An SBC that is at least 51% owned by one or more women, or in the case of any publicly owned business, at least 51% of the stock is owned by women, and women control the management and daily business operations.

1.06 Fraud, Waste and Abuse

As defined in the SBIR Policy Directive section 9(f), fraud includes any false representation about a material fact or any intentional deception designed to deprive the United States unlawfully of something of value or to secure from the United States a benefit, privilege, allowance, or consideration to which an individual or business is not entitled. Waste includes extravagant, careless, or needless expenditure of Government funds, or the consumption of Government property, that results from deficient practices, systems, controls, or decisions. Abuse includes any intentional or improper use of Government resources, such as misuse of rank, position, or authority or resources. Examples of fraud, waste, and abuse relating to the SBIR Program include, but are not limited to:

(i) misrepresentations or material, factual omissions to obtain, or otherwise receive funding under, an SBIR award;

(ii) misrepresentations of the use of funds expended, work done, results achieved, or compliance with program requirements under an SBIR award;

(iii) misuse or conversion of SBIR award funds, including any use of award funds while not in full compliance with SBIR Program requirements, or failure to pay taxes due on misused or converted SBIR award funds;

(iv) fabrication, falsification, or plagiarism in applying for, carrying out, or reporting results from an SBIR award;

(v) failure to comply with applicable federal costs principles governing an award;

(vi) extravagant, careless, or needless spending;

(vii) self-dealing, such as making a sub-award to an entity in which the PI has a financial interest;

(viii) acceptance by agency personnel of bribes or gifts in exchange for grant or contract awards or other conflicts of interest that prevents the Government from getting the best value; and

(ix) lack of monitoring, or follow-up if questions arise, by agency personnel to ensure that awardee meets all required eligibility requirements, provides all required certifications, performs in accordance with the terms and conditions of the award, and performs all work proposed in the application.

Report any allegations of fraud, waste and abuse to:

Department of Commerce
Office of Inspector General
Ben Franklin Station, Post Office Box 612
Washington, D.C. 20044

Telephone:

Toll free	1-800-424-5197
TTD	1-855-860-6950
Local	202-482-2495

e-mail: hotline@oig.doc.gov

2.0 CERTIFICATIONS

2.01 Funding Agreement Certification

Awardees will be required to certify size, ownership and other SBIR Program requirements at the time of award and during the funding agreement life cycle using the SBIR Funding Agreement Certification and the SBIR Funding Agreement Certification – Life-Cycle Certification, which are provided in Appendix B of this FFO.

2.02 Research Activities Involving Human Subjects, Human Tissue, Data or Recordings Involving Human Subjects Including Software Testing

Any application that includes research activities involving human subjects, human tissue/cells, or data or recordings from or about human subjects, must satisfy the requirements of the Common Rule for the Protection of Human Subjects (“Common Rule”), codified for the Department of Commerce at 15 C.F.R. Part 27. Research activities involving human subjects who fall within one or more of the classes of vulnerable subjects found in 45 C.F.R. Part 46, Subparts B, C and D must satisfy the requirements of the applicable subpart(s). In addition, any such application that includes research activities on these subjects must be in compliance with all applicable statutory requirements imposed upon the Department of Health and Human Services (DHHS) and other Federal agencies, all regulations, policies and guidance adopted by DHHS, the Food and Drug Administration, and other Federal agencies on these topics, and all Executive Orders and Presidential statements of policy on applicable topics. (Regulatory Resources: <http://www.hhs.gov/ohrp/humansubjects/index.html> which includes links to FDA regulations, but may not include all applicable regulations and policies).

NIST uses the following Common Rule definitions for research and human subjects research:

Research: A systematic investigation, including research development, testing and evaluation, designed to develop or contribute to generalizable knowledge. Activities which meet this definition constitute research for purposes of this policy, whether or not they are conducted or supported under a program which is considered research for other purposes. For example, some demonstration and service programs may include research activity.

Human Subject: A living individual about whom an investigator (whether professional or student) conducting research obtains data through intervention or interaction with the individual or identifiable private information.

- (1) *Intervention* includes both physical procedures by which data are gathered and manipulations of the subject or the subject's environment that are performed for research purposes.
- (2) *Interaction* includes communication or interpersonal contact between investigator and subject.
- (3) *Private information* includes information about behavior that occurs in a context in which an individual can reasonably expect that no observation or recording is taking place, and information which has been provided for specific purposes by an individual and which the individual can reasonably expect will not be made public (for example, a medical record). Private information must be individually identifiable (i.e., the identity of the subject is or may readily be ascertained by the investigator

associated with the information) in order for obtaining the information to constitute research involving human subjects.

See 15 C.F.R. § 27.102 Definitions.

- 1) **Requirement for Federalwide Assurance.** If the application is accepted for [or awarded] funding, organizations that have an IRB are required to follow the procedures of their organization for approval of exempt and non-exempt research activities that involve human subjects. Both domestic and foreign organizations performing non-exempt research activities involving human subjects will be required to have protocols approved by a cognizant, active IRB currently registered with the Office for Human Research Protections (OHRP) within the DHHS that is linked to the engaged organizations. All engaged organizations must possess a currently valid Federalwide Assurance (FWA) on file from OHRP. Information regarding how to apply for an FWA and register an IRB with OHRP can be found at <http://www.hhs.gov/ohrp/assurances/index.html>. NIST relies only on OHRP-issued FWAs and IRB Registrations for both domestic and foreign organizations for NIST supported research involving human subjects. NIST will not issue its own FWAs or IRB Registrations for domestic or foreign organizations.
- 2) **Administrative Review.** NIST reserves the right to make an independent determination of whether an applicant's activities include research involving human subjects. NIST will conduct an independent administrative review of all applications accepted for funding that include research involving human subjects that were approved by a non-NIST Institutional Review Board (IRB). Research may not start until the NIST Human Subjects Protection Office (HSPO) issues institutional review approval for final action by the NIST Grants Officer. (15 C.F.R. § 27.112 Review by Institution.) If NIST determines that an application includes research activities which involve human subjects, the applicant will be required to provide additional information for review and approval. The documents required for funded proposals are listed in each section below. Most such documents will need to be produced during the proposal review process; however, the Grants Officer may allow final versions of certain required documents to be produced at an appropriate designated time post-award. If an award is issued, no research activities involving human subjects shall be initiated or costs incurred for those activities under the award until the NIST Grants Officer issues written approval. Retroactive approvals are not permitted.
- 3) **Required documents for proposal review. All applications involving human subject research must clearly indicate, by separable task, all research activities believed to be exempt or non-exempt research involving human subjects, the expected institution(s) where the research activities involving human subjects may be conducted, and the institution(s) expected to be engaged in the research activities.**
 - a. **Not research determination.** If an activity/task involves human subjects as defined in the Common Rule, but the applicant participant(s) indicates to NIST that the

activity/task is not research as defined in the Common Rule, the following information may be requested for that activity/task:

- (1) Justification, including the rationale for the determination and such additional documentation as may be deemed necessary by NIST to review and/or support a determination that the activity/task in the application is not research as defined in the Common Rule.
- (2) If the applicant participant(s) used a cognizant IRB that provided a determination that the activity/task is not research, a copy of that determination documentation must be provided to NIST. The applicant participant(s) is not required to establish a relationship with a cognizant IRB if they do not have one.

NIST will review the information submitted and may coordinate further with the applicant before determining whether the activity/task will be defined as research under the Common Rule in the applicable NIST financial assistance program or project.

b. Exempt research determination with no IRB. If the application appears to NIST to include exempt research activities, and the performer of the activity or the supplier and/or the receiver of the biological materials or data from human subjects **does not** have a cognizant IRB to provide an exemption determination, the following information may be requested during the review process so that NIST can evaluate whether an exemption under the Common Rule applies (see 15 C.F.R. § 27.101(b), (c) and (d)).

- (1) The name(s) of the institution(s) where the exempt research will be conducted.
- (2) The name(s) of the institution(s) providing the biological materials or data from human subjects will be provided.
- (3) A copy of the protocol for the research to be conducted; and/or the biological materials or data from human subjects to be collected/provided, not pre-existing samples (*i.e.*, will proposed research collect only information without personal identifiable information, will biological materials or data be de-identified and when and by whom was the de-identification performed, how were the materials or data originally collected).
- (4) For pre-existing biological materials or data from human subjects, provide copies of the consent forms used for collection and a description of how the materials or data were originally collected and stripped of personal identifiers. If copies of consent forms are not available, explain.
- (5) Any additional clarifying documentation that NIST may deem necessary in order to make a determination whether the activity/task or use of biological materials or data from human subjects is exempt under the Common Rule.

c. Research review with an IRB. If the application appears to NIST to include research activities (exempt or non-exempt) involving human subjects, and the proposed performer of the activity has a cognizant IRB registered with OHRP, and linked to

their Federalwide Assurance, the following information may be requested during the review process:

- (1) The name(s) of the institution(s) where the research will be conducted;
- (2) The name(s) and institution(s) of the cognizant IRB(s), and the IRB registration number(s);
- (3) The FWA number of the applicant linked to the cognizant IRB(s);
- (4) The FWAs associated with all organizations engaged in the planned research activity/task, linked to the cognizant IRB;
- (5) If the IRB review(s) is pending, the estimated start date for research involving human subjects;
- (6) The IRB approval date (if currently approved for exempt or non-exempt research);
- (7) If any of the engaged organizations has applied for or will apply for an FWA or IRB registration, those details should be clearly provided for each engaged organization.

If the application includes research activities involving human subjects to be performed in the first year of an award, additional documentation may be requested by NIST during pre-award review for those performers, and may include the following for those research activities:

- (1) A signed (by the study principal investigator) copy of each applicable final IRB-approved protocol;
- (2) A signed and dated approval letter from the cognizant IRB(s) that includes the name of the institution housing each applicable IRB, provides the start and end dates for the approval of the research activities, and any IRB-required interim reporting or continuing review requirements;
- (3) A copy of any IRB-required application information, such as documentation of approval of special clearances (*i.e.*, biohazard, HIPAA, etc.) conflict-of-interest letters, or special training requirements;
- (4) A brief description of what portions of the IRB submitted protocol are specifically included in the application submitted to NIST, if the protocol includes tasks not included in the application, or if the protocol is supported by multiple funding sources. For protocols with multiple funding sources, NIST will not approve the study without a non-duplication-of-funding letter indicating that no other federal funds will be used to support the tasks proposed under the proposed research or ongoing project;
- (5) If a new protocol will only be submitted to an IRB if an award from NIST is issued, a draft of the proposed protocol;
- (6) Any additional clarifying documentation that NIST may request during the review process to perform the NIST administrative review of research involving human subjects. (*See 15 C.F.R. § 27.112 Review by Institution.*)

This clause reflects the existing NIST policy and requirements for Research Involving Human Subjects. Should the policy be revised prior to award, a clause reflecting the policy current at time of award may be incorporated into the award.

If the policy is revised after award, a clause reflecting the updated policy may be incorporated into the award.

For more information regarding research projects involving human subjects, contact Anne Andrews, Director, NIST Human Subjects Protection Office (e-mail: anne.andrews@nist.gov; phone: (301) 975-5445).

2.03 Research Applications Involving Live Vertebrate Animals

Any application that includes research activities involving live vertebrate animals, that are being cared for, euthanized, or used by participants in the application to accomplish research goals, teaching, or testing, must meet the requirements of the Animal Welfare Act (AWA) (7 U.S.C. § 2131 et seq.), and the AWA final rules (9 C.F.R. Parts 1, 2, and 3), and if appropriate, the Good Laboratory Practice for Non-clinical Laboratory Studies (21 C.F.R. Part 58). In addition, such applications should be in compliance with the “*U.S. Government Principles for Utilization and Care of Vertebrate Animals Used in Testing, Research, and Training.*” The Principles and guidance on these Principles are available in the National Research Council's “*Guide for the Care and Use of Laboratory Animals,*” which can be obtained from National Academy Press, 500 5th Street, N.W., Department 285, Washington, DC 20055, or as a free PDF online at <http://www.nap.edu/catalog/12910/guide-for-the-care-and-use-of-laboratory-animals-eighth>.

The following requirements do not apply to proposed research using preexisting images of animals or to research plans that do not include live animals. These regulations also do not apply to obtaining stock items from animal material suppliers (*e.g.*, tissue banks), such as cell lines and tissue samples, or from commercial food processors, where the vertebrate animal was euthanized for food purposes and not for the purpose of sample collection.

Custom Collections Harvested from Live Vertebrate Animals: NIST requires documentation for obtaining custom samples from live vertebrate animals from animal material suppliers and other organizations (*i.e.*, universities, companies, and government laboratories, etc.). Custom samples includes samples from animal material suppliers, such as when a catalog item indicates that the researcher is to specify the characteristics of the live vertebrate animal to be used, or how a sample is to be collected from the live vertebrate animal.

Field Studies of Animals: Some field studies of animals may be exempt under the Animal Welfare Act from full review and approval by an animal care and use committee, as determined by each institution. Field study is defined as “*...a study conducted on free-living wild animals in their natural habitat.*” However, this term excludes any study that involves an invasive procedure or that harms or materially alters the behavior of an animal under study. Field studies, with or without invasive procedures, may also require obtaining

appropriate federal or local government permits (*e.g.*, marine mammals, endangered species etc.). If the applicant's institution requires review and approval by an animal care and use committee, NIST will require that documentation to be provided as described below.

1) Requirement for Assurance.

An applicable assurance for the care and use of the live vertebrate animal(s) to be used in the proposed research is required. NIST accepts three types of assurances, as may be applicable. NIST may request documentation to confirm an assurance, if adequate confirmation is not available through an assuring organization's website.

The cognizant Institutional Animal Care and Use Committee (IACUC) where the research activity is located may hold one or more applicable assurance, including:

- Animal Welfare Assurance from the Office of Laboratory Animal Welfare (OLAW) indicated by the OLAW assurance number, *i.e.*, A-1234;
- USDA Animal Welfare Act certification indicated by the certification number, *i.e.*, 12-R-3456;
- Association for the Assessment and Accreditation of Laboratory Animal Care (AAALAC) indicated by providing the organization name accredited by AAALAC as listed in the AAALAC Directory of Accredited Organizations.

2) Administrative Review.

NIST reserves the right to make an independent determination of whether an applicant's research activities involve live vertebrate animals or custom samples from, or field studies with live vertebrate animals. If NIST determines that the application includes research activities, field studies, or custom samples involving live vertebrate animals, the applicant will be required to provide additional information for review and approval. The documents required for funded proposals are listed in each section below. Some may be requested for a pre-review during the proposal review process; however, the Grants Officer may allow final versions of certain required documents to be produced at an appropriate designated time post-award. If an award is issued, no research activities involving live vertebrate animals subjects shall be initiated or costs incurred for those activities under the award until the NIST Grants Officer issues written approval.

3) Required documents for proposal review. *The applicant should clearly indicate in the application, by separable task, all research activities believed to include research involving live vertebrate animals and the institution(s) where the research activities involving live vertebrate animals may be conducted.*

Documentation of Research Review by an IACUC: If the applicant's application appears to include research activities, field studies, or custom sample collections involving live vertebrate animals the following information regarding review by an applicable IACUC may be requested during the application review process:

- (1) The name(s) of the institution(s) where the research involving live vertebrate animals will be conducted and/or custom samples collected;
- (2) The assurance type and number, as applicable, for the cognizant Institutional Animal Care and Use Committee (IACUC) where the research activity is located. [For example: Animal Welfare Assurance from the Office of Laboratory Animal Welfare (OLAW) should be indicated by the OLAW assurance number, i.e. A-1234; an USDA Animal Welfare Act certification should be indicated by the certification number i.e. 12-R-3456; and an Association for the Assessment and Accreditation of Laboratory Animal Care (AAALAC) should be indicated by AAALAC.]
- (3) The IACUC approval date for the Animal Study Protocol (ASP) (if currently approved);
- (4) If the review by the cognizant IACUC is pending, the estimated- start date for research involving vertebrate animals;
- (5) If any assurances or IACUCs need to be obtained or established, that should be clearly stated.
- (6) If any special permits are required for field studies, those details should be clearly provided for each instance, or indicated as pending.

If the application includes research activities involving vertebrate animals to be performed in the first year of an award, additional documentation may be requested by NIST during pre-award review for those performers, and may include the following for those research activities, which may also include field studies, custom sample collections involving live vertebrate animals:

- (1) A signed (by the Principal Investigator) copy of the IACUC approved ASP;
- (2) Documentation of the IACUC approval indicating the approval and expiration dates of the ASP; and
- (3) If applicable, a non-duplication-of-funding letter if the ASP is funded from several sources.
- (4) If a new ASP will only be submitted to an IACUC if an award from NIST is issued, a draft of the proposed ASP may be requested.
- (5) Any additional clarifying documentation that NIST may request during review of applications to perform the NIST administrative review of research involving live vertebrate animals.

This clause reflects the existing NIST policy for Research Involving Live Vertebrate Animals. Should the policy be revised prior to award, a clause reflecting the policy current at time of award may be incorporated into the award.

If the policy is revised after award, a clause reflecting the updated policy may be incorporated into the award.

For more information regarding research projects involving live vertebrate animals, contact Linda Beth Schilling, Senior Analyst (e-mail: linda.schilling@nist.gov; phone: 301-975-2887).

2.04 Certifications Regarding Federal Felony and Federal Criminal Tax Convictions, Unpaid Federal Tax Assessments and Delinquent Federal Tax Returns

In accordance with Federal appropriations law, an authorized representative of the selected applicant(s) may be required to provide certain pre-award certifications regarding federal felony and federal criminal tax convictions, unpaid federal tax assessments, and delinquent federal tax returns.

3.0 APPLICATION PREPARATION INSTRUCTIONS AND REQUIREMENTS

3.01 Phase I Application Requirements

Only Phase I applications may be submitted in response to this FFO. FY 2017 Phase II applications are currently not being accepted. Rather, NIST will publish an FFO approximately 30 days prior to the end of the FY 2016 Phase I performance period to request FY 2017 Phase II applications, provide the instructions to prepare an FY 2017 Phase II application, and provide the closing date for FY 2017 Phase II applications. Only FY 2016 Phase I awardees will be eligible to submit FY 2017 Phase II applications.

The application must provide sufficient information to demonstrate that the proposed work represents a sound approach to the investigation of an important scientific or engineering innovation worthy of support. The application must sufficiently address the applicable subtopic in section 9. The application must be self-contained and written with all the care and thoroughness of a scientific paper submitted for publication. It should indicate a thorough knowledge of the current status of research in the subtopic area addressed by the application. Each application should be checked carefully by the applicant to ensure inclusion of all essential material needed for a complete evaluation.

The application must not only be responsive to the specific NIST program interests described in Section 9 of the FFO, but also must serve as the basis for technological innovation leading to new commercial products, processes, or services that benefit the public.

NIST reserves the right to not submit an application for technical review if NIST determines the application has insufficient scientific and technical information, or fails to comply with the administrative procedures as outlined in the applicable Screening Criteria in Section 4.02. Applications that do not meet the screening criteria will be returned to the applicant without further consideration.

All applicants are required to provide information for SBA's database (www.SBIR.gov). The following are examples of the data to be entered by applicants into the database:

- Any business concern or subsidiary established for the commercial application of a product or service for which an SBIR award is made.
- Revenue from the sale of new products or services resulting from the research conducted under each Phase II award.
- Additional investment from any source, other than Phase I or Phase II awards, to further the research and development conducted under each Phase II award.
- Updated information in the SBA Tech-Net database on sbir.gov for any prior award received by the SBC. The SBC may apportion sales or additional investment information relating to more than one Phase II award among those awards, if it notes the apportionment for each award.

Each Phase II awardee is required to update appropriate information on the award in the database upon completion of the last program objective under the funding agreement and is requested to voluntarily update the information in the database annually thereafter for a minimum period of 5 years.

3.02 Phase I Application

A complete application must include a Technical Proposal (described below) and the forms and documents listed in Section 8.01.

An applicant may submit applications on multiple subtopics or multiple applications on one subtopic under this FFO. When the proposed innovation applies to more than one subtopic, the applicant must submit its application under the subtopic that is most relevant to the applicant's technical concept.

The Technical Proposal is limited to 25 pages. Additional pages beyond the 25-page limit will not be considered in the evaluation process. Pages should be of standard size (8 1/2" x 11"; 21.6 cm x 27.9 cm) with margins of 2.5 cm and type at least 10 point font. All units of measurement should be presented in metric units.

The Technical Proposal (see Section 8.01.(6) of this FFO) portion of the application requires the following:

- (a) Cover Sheet (3.02.01) pages 1 and 2, and**
- (b) Technical Content (3.02.02) pages 3 through 25.**

The listing of all forms and documents needed to complete the application is given in Section 8.01 of this FFO. The additional required forms and documents in Section 8.01 are not included in the 25 page count.

See Section 6.0 for information on the submission of applications in response to this FFO.

3.02.01 Cover Sheet

Complete the Cover Sheet (Appendix A) as pages 1 and 2 of the Technical Proposal. If you check 'Yes' on #12, your contact information will be provided to the NIST Hollings Manufacturing Extension Partnership (MEP). You may be contacted by your local MEP to explore business-related support services that could potentially benefit your proposed project.

The applicant must provide in the space available on the Cover Sheet an abstract (limited to 200 words) and summary of commercial potential of the research results (limited to 100 words). Each awardee's abstract and summary of commercial potential will be published on the [NIST SBIR website](#) and www.sbir.gov and, therefore, must not contain proprietary information.

3.02.02 Technical Content

Beginning on page 3 of the Technical Proposal, include the following items with headings as shown:

(1) Identification and Significance of the Problem or Opportunity. Make a clear statement of the specific research problem or opportunity addressed, its innovativeness, commercial potential, and why it is important. Explain how it applies to a specific subtopic in Section 9.

(2) Phase I Technical Objectives. State the specific objectives of the Phase I effort, including the technical questions it will try to answer, to determine the feasibility of the proposed approach.

(3) Phase I Work Plan. Include a detailed description of the Phase I feasibility research plan. The plan should indicate what will be done, where it will be done, and how the research will be carried out. The method(s) planned to achieve each objective or task should be discussed in detail.

(4) Related R/R&D. Describe significant R/R&D that is directly related to the application, including any conducted by the principal investigator or by the proposing SBC. Describe how it relates to the proposed effort, and describe any planned coordination with outside sources. The applicant must persuade evaluators of his or her awareness of key, recent R/R&D conducted by others in the specific topic area.

(5) Key Individuals and Bibliography of Related Work. Identify key individuals involved in Phase I, including their related education, experience, and publications. Where vitae are extensive, summaries that focus on the most relevant experience and publications are desired and may be necessary to meet application size limitations.

(6) Relationship with Future R/R&D. Discuss the significance of the Phase I effort in providing a foundation for the Phase II R/R&D effort. Also state the anticipated results of the proposed approach if Phases I and II of the project are successful.

(7) Facilities and Equipment. A detailed description, availability, and location of instrumentation and physical facilities proposed for Phase I should be provided.

(8) Consultants, Contracts, and Subawards. The purpose of this section is to show that any third party research assistance would materially benefit the proposed effort and that arrangements for such assistance are in place at time of application submission.

For Phase I, a minimum of two-thirds of the research and/or analytical effort must be performed by the awardee. Outside involvement in the project is encouraged where it strengthens the conduct of the research. Outside involvement is not a requirement of this program and is limited to no more than one-third of the research and/or analytical effort in Phase I. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-third of the total award.

No individual or entity may serve as consultant, contractor, or subrecipient if they:

1. had any role in suggesting, developing, or reviewing the NIST subtopic; or
2. have been the recipient of any NIST information on the subtopic not available to the public.

1. Consultant - A person outside the firm, named in the application as contributing to the research, must provide a signed statement confirming his/her availability, role in the project, and agreed consulting rate for participation in the project. This statement is part of the 25 page limitation.

2. Contract - Similarly, where a contract is involved in the research, the contractor institution must furnish a letter signed by an appropriate official describing the programmatic arrangements and confirming its agreed participation in the research, with its proposed budget for this participation. This letter is part of the 25 page limitation.

3. Subawards - As the funding instrument used in this program is financial assistance, an awardee might pass through funds to another organization to carry out part of the Federally-supported project. A "subaward" relationship fits the circumstances more appropriately than a contract to carry out part of the Federally-supported project. See 2 CFR §§ 200.92 (subaward), 200.93 (subrecipient), and 200.330 (Subrecipient and contractor determinations), respectively.

The subrecipient institution must furnish a letter signed by an appropriate official describing the programmatic arrangements and confirming its agreed participation in the research, with its proposed budget for this participation. This letter is part of the 25 page limitation.

(9) Potential Commercial Application. A program goal is to provide opportunities for small businesses to convert research into technological innovation in the private sector. All

proposed research should have some potential commercial outcome. Describe in detail the commercial potential of the proposed research, how commercialization would be pursued and potentially used by the private sector and/or the Federal Government. Include any optional letters of support and relevant supporting material such as references to journal articles, literature, or government publications. Provide any indicators of commercial potential and address the following:

(a) Market opportunity – Describe the current and anticipated target market, the size of the market, and include a brief profile of the potential customer(s).

(b) Technology and competition – Describe the competitive landscape, the value proposition and competitive advantage of the product or service enabled by the proposed innovation. Also include what critical milestones must be met to get the product or process to market and the resources required to address the business opportunity.

(c) Finances – Describe your strategy for financing the innovation beyond the SBIR award. Describe the existence of any outside, non-SBIR funding or partnering commitments including any Phase II funding commitments from private sector or non-SBIR funding sources and/or the existence of Phase III follow-on commitments for the subject research.

(10) Cooperative Research and Development Agreements (CRADA). State if the applicant is a former or current CRADA partner with NIST, or with any other Federal agency, naming the agency, title of the CRADA, and any relationship with the proposed work. The statement of work of an SBIR award awarded under this FFO cannot overlap with the statement of work of an existing CRADA with any federal agency, including NIST, with the awardee. NIST will consider whether there is any overlap on a case by case basis.

(11) Guest Researcher. State if the applicant or any of its consultants, contractors, or subrecipients or their employees is a guest researcher at NIST (see <http://www.nist.gov/tpo/collaborations/guestresearchers.cfm>), naming the sponsoring laboratory.

(12) Cost Sharing. Cost sharing is not required and is not considered under an evaluation factor in consideration of Phase I applications.

(13) Similar Applications or Awards. WARNING -- While it is permissible to submit identical applications or applications containing a significant amount of essentially equivalent work for consideration under numerous Federal program funding announcements, **it is unlawful to enter into a funding agreement requiring essentially equivalent work to an SBIR award (see 15 U.S.C. § 638(bb)(3)).** If there is any question concerning this, it must be disclosed to the soliciting agency or agencies before award.

If an application submitted in response to this FFO is substantially the same as another application that has been funded, is now being funded, or is pending with another Federal

Agency, the applicant must provide the following information:

(a) Names and addresses of agencies to which an application was submitted or from which an award was received.

(b) Date of application submission or date of award.

(c) Title, number, and date of FFO(s) under which an application was submitted or award received.

(d) Specific applicable research topic(s) for each application submitted or award received.

(e) Title of research projects for each application submitted or award received.

(f) Name and title of principal investigator or project manager for each application submitted or award received.

If no equivalent application is under consideration or award for equivalent work received, a statement to that effect **must** be included in this section of the technical content area of the application.

(14) Prior SBIR Phase II Awards. If the SBC has received more than 15 Phase II awards in the prior 5 fiscal years, the SBC must submit in its Phase I application: name of the awarding agency; date of award; funding agreement number; amount of award; topic or subtopic title; follow-on agreement amount; source and date of commitment; and current commercialization status for each Phase II award. This required application information will not be counted toward the Technical Proposal pages limitation.

4.0 METHOD OF SELECTION AND EVALUATION CRITERIA

4.01 Introduction

All applications will be evaluated and judged on a competitive basis. Applications will be evaluated using only information provided in the application. Applications will be initially screened to determine responsiveness, eligibility, and completeness (see Section 4.02). Applications passing these initial screenings will be technically evaluated by NIST employees in accordance with the evaluation criteria (see Section 4.03). Each application will be judged on its own merit. NIST is under no obligation to fund any application or any specific number of applications in a given topic. NIST may elect to fund several or none of the applications for the same topic or subtopic.

4.02 Phase I Screening Criteria

Please carefully read the entire FFO and review the following Phase I Screening Criteria to assure that your application meets NIST requirements. Phase I applications that do not satisfy all the screening criteria will be returned to the applicant without further review and will be eliminated from consideration for award. However, NIST, in its sole discretion, may continue the review process for an application that is missing minor non-substantive information which may easily be rectified or cured. The screening criteria are:

- (1) The application must be received by NIST before the deadline specified in Section 6.01.
- (2) The proposing firm must qualify as eligible according to the criteria provided in Section 1.03.
- (3) The Phase I application must meet all of the requirements stated in Section 3.01 and Section 3.02 and include all forms and certifications listed in Section 8.01.
- (4) All required forms must be complete and signed as necessary.
- (5) The Technical Proposal must contain the Cover Sheet (Appendix A), Technical Content (Section 3.02.02), and must not exceed 25 pages.
- (6) Letters from affiliated parties such as contractors (Section 3.02 (8)) must be included in the Technical Proposal if contractors are used. These pages count as part of the 25 page limitation.
- (7) The Phase I application is submitted only under one of the subtopics in Section 9 and clearly addresses research for that subtopic.
- (8) The Phase I total proposed budget must not exceed \$100,000. For Phase I, a minimum of two-thirds of the research and/or analytical effort must be performed by the awardee. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-third of the total award (Section 1.03).
- (9) The feasibility research duration for the Phase I project must not exceed 6 months.

4.03 Phase I Evaluation Criteria

Phase I applications that comply with the screening criteria in Section 4.02 will undergo an internal, two-step scored review process.

Step 1: Technical Review. The applications will be evaluated by three NIST scientists or engineers in accordance with the following, equally weighted criteria, on a scale of 1 to 5:

- (1) The soundness of the technical approach to the proposed research.
- (2) The likelihood the proposed effort will result in significant results leading to a product within the subtopic.
- (3) The likelihood the proposed approach will contribute toward the field of study of the subtopic.
- (4) Qualifications of the proposed principal/key investigators, supporting staff, and consultants as they relate to accomplishing the proposed research effort.

Technical reviewers will base their evaluations only on information contained in the application.

Applicants should be specific and clear when writing their applications and not assume information not clearly spelled out can be inferred by the reviewer. No technical clarifications may be made after application submission. The Selecting Official will determine the average score above which applications will be considered “technically superior.” Applications not rated as technically superior will not be considered further.

Step 2: Evaluation Panel. A panel composed of at least 3 NIST employees will review the content of applications rated as technically superior in Step 1, score them based on the following evaluation factors, and by consensus develop a final ranking:

- (1) The Economic impact (e.g., ability of the company to develop a commercially viable product, service or process); record of past performance for SBIR and STTR awards; assessment of whether the applicant’s participation would diversify the nature and types of firms participating in the NIST SBIR program; existence of outside, non-SBIR, funding or partnering commitments; and/or the presence of other relevant supporting material contained in the application that indicates the commercial potential of the idea (such as optional letters of support and references to journal articles, literature, and Government publications). (10 points)
- (2) The SBIR program priorities including manufacturing-related research; energy efficiency or renewable energy; participation by woman-owned and socially and economically disadvantaged SBCs, and SBCs from HUBZones or under-served states. (5 points)

4.04 Phase I Award Selections

Final selection decisions will be made by the Selecting Official, the Director of the NIST Technology Partnerships Office, or designee, based upon scores assigned by the technical reviewers and the rankings assigned by the panel, diversity across the sub-topics and participants, possible duplication of other federally-funded research, and the availability of funding. The Selecting Official may give preference to applicants that have received fewer

than 20 SBIR awards in the past. In the event of a “tie” between applications, manufacturing-related projects, as well as those regarding energy efficiency and renewable energy system will receive priority in the award selection process. NIST may select some, all, or none of the applications, or part(s) of any particular application. Subsequent to the assessment and prior to award, NIST may ask for supplemental information and may negotiate the scope and amount of the award. The final approval of selected applications and issuance of awards will be by the NIST Grants Officer. The award decisions of the NIST Grants Officer are final.

4.04.01 Federal Awarding Agency Review of Risk Posed by Applicants

After applications are proposed for funding by the selecting official, the NIST Grants Management Division (GMD) performs administrative reviews, which may include a review of the financial stability of an applicant, the quality of the applicant’s management systems, the history of performance, and/or the applicant’s ability to effectively implement statutory, regulatory, or other requirements imposed on non-Federal entities. Upon review of these factors, if appropriate, special conditions that correspond to the degree of risk may be applied to an award.

In addition, prior to making an award where the total Federal share is expected to exceed the simplified acquisition threshold (currently \$150,000), NIST GMD will review and consider the publicly available information about that applicant in the Federal Awardee Performance and Integrity Information System (FAPIS). An applicant may, at its option, review and comment on information about itself previously entered into FAPIS by a Federal awarding agency. As part of its review of risk posed by applicants, NIST GMD will consider any comments made by the applicant in FAPIS in making its determination about the applicant’s integrity, business ethics, and record of performance under Federal awards.

4.04.02 Release of Proposal Review Information

After final award decisions have been announced, the reviewers’ technical evaluations of applications that passed the screening criteria will be provided to the applicant with written notification of award/non-award. The identity of the reviewers will not be disclosed.

5.0 CONSIDERATIONS

5.01 Awards

Through 2. C.F.R. § 1327.101, the Department of Commerce adopted Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards at 2 C.F.R. Part 200, which apply to awards in this program. Refer to <http://go.usa.gov/SBYh> and <http://go.usa.gov/SBg4>.

The DoC Financial Assistance Standard Terms and Conditions will apply to this award. A current version of these terms, from December 2014, is available at <http://go.usa.gov/hKbj>.

The DoC Pre-Award Notification Requirements for Grants and Cooperative Agreements, 79 FR 78390 (December 30, 2014), are applicable to this FFO and are available at <http://go.usa.gov/hKkR>.

Contingent upon availability of funds, NIST anticipates making a total number of approximately twelve (12) Phase I awards of no more than \$100,000 each. The total performance period shall be no more than seven (7) months beginning on the agreement start date. A period of one (1) month is allotted after the six (6) month R&D duration for the awardee to prepare and submit a final report.

Phase II awards shall be for no more than \$300,000. The R&D activity period of performance in Phase II will depend upon the scope of the research, but should not exceed 24 months. One year after completing the R&D activity, the awardee shall be required to report on its commercialization activities. The total period of performance for Phase II is 36 months.

It is anticipated that approximately half of the Phase I awardees will receive Phase II awards, depending upon the availability of funds. To provide for an in-depth review of the Phase I final report and the Phase II application, Phase II awards will be made approximately 4 months after the completion of Phase I, contingent upon availability of funds.

Funding for the program listed in this FFO is contingent upon the availability of appropriations. In no event will NIST or DoC be responsible for application preparation costs. This FFO does not obligate NIST or DoC to make any awards under either Phase I or Phase II. Furthermore, NIST will not fund any costs incurred by the applicants before awards are made. Publication of this FFO does not oblige NIST or DoC to award any specific project or to obligate any available funds.

5.02 Reporting Requirements

Phase I awardees will be required to submit a progress report three months after award and a final report seven months after award.

Progress reports should include technical details regarding the research conducted up to that point in the project and provide detailed plans for the next stages of the project. Consideration will be given to changes from the solicited and proposed milestones if results from experimentation warrant a deviation from plan. Inclusion of proprietary information within the progress reports and final report may be necessary in order to effectively communicate progress and gain appropriate consultation from NIST experts regarding next steps. All such proprietary information must be marked by the awardee according to instructions provided in Section 5.04.02.(d)(1).

Final reports shall include a single-page project summary as the first page. The remainder of the report should indicate the research objectives, research work carried out, results obtained, and estimates of technical feasibility.

All final reports must carry an acknowledgment on the cover page such as: "This material is based upon work supported by the National Institute of Standards and Technology (NIST) under cooperative agreement _____. Any opinions, findings, conclusions or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of NIST."

To help assess the effectiveness of our program in meeting programmatic and SBIR objectives, NIST may periodically request information from small businesses about progress taken towards commercialization of the technology after the completion of Phase I and II awards.

5.03 Payment Schedule

Cooperative agreements will include an award term with electronic payment system information. Pursuant to 2 C.F.R. § 200.305 awardees are to be paid in advance, provided they maintain or demonstrate the willingness to maintain: written procedures that minimize the time elapsing between the transfer of funds and disbursement by the recipient, and financial management systems that meet the standards for fund control and accountability as established in 2 C.F.R. § 200.302. Advances of funds to a recipient organization shall be limited to the minimum amounts needed and be timed to be in accordance with the actual, immediate cash requirements of the recipient organization in carrying out the purpose of the approved program or project.

5.04 Innovations, Inventions and Patents

5.04.01 Proprietary Information Proposals

Information contained in unsuccessful proposals will remain the property of the applicant. The Government may, however, retain copies of all proposals. Public release of information in any proposal submitted will be subject to existing statutory and regulatory requirements. If proprietary information is provided by an applicant in a proposal, which constitutes a trade secret, proprietary commercial or financial information, confidential personal information or data affecting the national security, it will be treated in confidence, to the extent permitted by law. This information must be clearly marked by the applicant with the term "confidential proprietary information" and the following legend must appear on the title page of the proposal:

"These data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal. If a funding agreement is awarded to this applicant as a result of or in connection with the submission of these data,

the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained on pages_____of this proposal.”

Any other legend may be unacceptable to the Government and may constitute grounds for removing the proposal from further consideration, without assuming any liability for inadvertent disclosure. The Government will limit dissemination of such information to within official channels.

5.04.02 Rights in Data Developed Under SBIR Funding Agreements

In lieu of Department of Commerce Financial Assistance Standard Terms and Conditions (December 2014), Section D.03, the following term and condition will apply to and be included in all SBIR awards issues under this FFO:

(a) Definitions. As used in regards this FFO and awards made pursuant to this FFO: --
“Computer database” or “database” means a collection of recorded information in a form capable of, and for the purpose of, being stored in, processed, and operated on by a computer. The term does not include computer software.

“Computer software” (1) means: (i) computer programs that comprise a series of instructions, rules routines, or statements, regardless of the media in which recorded, that allow or cause a computer to perform a specific operation or series of operations; and (ii) recorded information comprising source code listings, design details, algorithms, processes, flow charts, formulas, and related material that would enable the computer program to be produced, created, or compiled; and (2) does not include computer databases or computer software documentation.

“Computer software documentation” means owner’s manuals, user’s manuals, installation instructions, operating instructions, and other similar items, regardless of storage medium, that explain the capabilities of the computer software or provide instructions for using the software.

“Data” means recorded information, regardless of form or the media on which it may be recorded. The term includes technical data and computer software. The term does not include information incidental to contract administration, such as financial, administrative, cost or pricing or management information.

“Form, fit, and function data” means data relating to items, components, or processes that are sufficient to enable physical and functional interchangeability as well as data identifying source, size, configuration, mating and attachment characteristics, functional

characteristics, and performance requirements. For computer software it means data identifying source, functional characteristics, and performance requirements but specifically excludes the source code, algorithms, processes, formulas, and flow charts of the software. “Limited rights data” means data (other than computer software) developed at private expense that embody trade secrets or are commercial or financial and confidential or privileged.

“Restricted computer software” means computer software developed at private expense and that is a trade secret; is commercial or financial and confidential or privileged; or is copyrighted computer software; including modifications of the computer software.

“SBIR data” means data first produced by an Awardee that is a small business concern in performance of a small business innovation research award issued under the authority of 15 U.S.C. § 638, which data are not generally known, and which data without obligation as to its confidentiality have not been made available to others by the Awardee or are not already available to the Government.

“SBIR rights” means the rights in SBIR data set forth in the SBIR Rights Notice of paragraph (d) of this clause.

“Technical data” means recorded information (regardless of the form or method of the recording) of a scientific or technical nature (including computer databases and computer software documentation). This term does not include computer software or financial, administrative, cost or pricing, or management data or other information incidental to contract administration. The term includes recorded information of a scientific or technical nature that is included in computer databases. (See 41 U.S.C. § 403(8)).

“Unlimited rights” means the right of the Government to use, disclose, reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, in any manner and for any purpose whatsoever, and to have or permit others to do so.

(b) Allocation of rights.

(1) Except as provided in paragraph (c) section regarding copyright, the Government shall have unlimited rights in—

- (i) Data specifically identified in this award as data to be delivered without restriction;
- (ii) Form, fit, and function data delivered under this award;
- (iii) Data delivered under this award (except for restricted computer software) that constitute manuals or instructional and training material for installation, operation, or routine maintenance and repair of items, components, or processes delivered or furnished for use under this award; and

(iv) All other data delivered under this award unless provided otherwise for SBIR data in accordance with paragraph (d) of this clause or for limited rights data or restricted computer software in accordance with paragraph (f) of this clause.

(2) The Awardee shall have the right to—

- (i) Assert copyright in data first produced in the performance of this award to the extent provided in paragraph (c)(1) of this clause;
- (ii) Protect SBIR rights in SBIR data delivered under this award in the manner and to the extent provided in paragraph (d) of this clause;
- (iii) Substantiate use of, add, or correct SBIR rights or copyright notices and to take other appropriate action, in accordance with paragraph (e) of this clause; and
- (iv) Withhold from delivery those data which are limited rights data or restricted computer software to the extent provided in paragraph (f) of this clause.

(c) Copyright.

(1) *Data first produced in the performance of this award.*

- (i) Except as otherwise specifically provided in this award, the Awardee may assert copyright subsisting in any data first produced in the performance of this award.
- (ii) When asserting copyright, the Awardee shall affix the applicable copyright notice of 17 U.S.C. § 401 or § 402 and an acknowledgment of Government sponsorship (including award number).
- (iii) For data other than computer software, the Awardee grants to the Government, and others acting on its behalf, a paid-up nonexclusive, irrevocable, worldwide license to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government. For computer software, the Awardee grants to the Government, and others acting on its behalf, a paid-up, nonexclusive, irrevocable, worldwide license in such copyrighted computer software to reproduce, prepare derivative works, and perform publicly and display publicly, by or on behalf of the Government.

(2) *Data not first produced in the performance of this award.* The Awardee shall not, without prior written permission of the Grants Officer, incorporate in data delivered under this award any data that are not first produced in the performance of this award unless the Awardee: (i) identifies such data; and (ii) grants to the Government, or acquires on its behalf, a license of the same scope as set forth in subparagraph (c)(1) of this clause.

(3) *Removal of copyright notices.* The Government will not remove any copyright notices placed on data pursuant to this paragraph (c), and will include such notices on all reproductions of the data.

(d) Rights to SBIR data.

(1) The Awardee is authorized to affix the following “SBIR Rights Notice” to SBIR data delivered under this award and the Government will treat the data, subject to the provisions of paragraphs (e) and (f) of this clause, in accordance with such Notice:

SBIR Rights Notice

These SBIR data are furnished with SBIR rights under Award No. _____ (and contract or subaward _____, if appropriate). For a period of 4 years, unless extended, after acceptance of all items to be delivered under this award, the Government will use these data for Government purposes only, and they shall not be disclosed outside the Government (including disclosure for procurement purposes) during such period without permission of the Awardee, except that, subject to the foregoing use and disclosure prohibitions, these data may be disclosed for use by support contractors and/or subrecipients. After the protection period, the Government has a paid-up license to use, and to authorize others to use on its behalf, these data for Government purposes, but is relieved of all disclosure prohibitions and assumes no liability for unauthorized use of these data by third parties, except that any such data that is also protected and referenced under a subsequent SBIR award shall remain protected through the protection period of that subsequent SBIR award. This Notice shall be affixed to any reproductions of these data, in whole or in part.

(End of notice)

(2) The Government’s sole obligation with respect to any SBIR data shall be as set forth in this paragraph (d).

(e) Omitted or incorrect markings.

(1) Data delivered to the Government without any notice authorized by paragraph (d) of this clause shall be deemed to have been furnished with unlimited rights. The Government assumes no liability for the disclosure, use, or reproduction of such data.

(2) If the unmarked data has not been disclosed without restriction outside the Government, the Awardee may request, within six months (or a longer time approved by the Grants Officer in writing for good cause shown) after delivery of the data, permission to have authorized notices placed on data at the Awardees expense, and the Grants Officer may agree to do so if the Awardee—

- (i) Identifies the data to which the omitted notice is to be applied;
- (ii) Demonstrates that the omission of the notice was inadvertent;
- (iii) Establishes that the use of the proposed notice is authorized; and
- (iv) Acknowledges that the Government has no liability with respect to the disclosure or use of any such data made prior to the addition of the notice or resulting from the omission of the notice.

(3) If the data has been marked with an incorrect notice the Grants Officer may—

- (i) Permit correction, at the Awardee’s expense, if the Awardee identifies the data and demonstrates that the correct notice is authorized, or

(ii) Correct any incorrect notices.

(f) Protection of limited rights data and restricted computer software. The Awardee may withhold from delivery qualifying limited rights data and restricted computer software that are not identified in paragraphs (b)(1)(i), (ii), and (iii) of this clause. As a condition to this withholding the Awardee shall identify the data being withheld and furnish form, fit, and function data instead.

(g) Contracting and Subawards. The Awardee shall obtain from its contractors and subawardees all data and rights therein necessary to fulfill the Awardee's obligations to the Government under this award. If a contractor or subawardee refuses to accept terms affording the Government those rights, the Awardee shall promptly notify the Grants Officer of the refusal and not proceed with the contract or subaward without further authorization in writing from the Grants Officer.

(h) Relationship to patents. Nothing contained in this subsection shall imply a license to the Government under any patent or be construed as affecting the scope of any license or other right otherwise granted to the Government.

5.04.03 NIST-Owned Patented Background Inventions

Awardees receiving SBIR awards for a subtopic based on a NIST-owned patented background invention, will, upon the license application by the awardee to a NIST licensing officer, be granted a non-exclusive research license to use those NIST-owned patented background inventions. SBIR applicants are hereby notified that no exclusive or non-exclusive commercialization license to make, use or sell products or services incorporating the NIST background invention is granted until an SBIR awardee applies for, negotiates and receives such a license. Awardees under subtopics based on NIST-owned patented background inventions will be given the opportunity to negotiate a non-exclusive commercialization license to such background inventions. If available, awardees may be given the opportunity to negotiate an exclusive commercialization license to such background inventions. License applications will be treated in accordance with Federal patent licensing regulations as provided in 37 C.F.R. Part 404.

5.04.05 Invention Reporting

SBIR awardees must report inventions to the NIST SBIR Program Office within 2 months of the inventor's report to the awardee. Inventions must also be reported through the iEdison Invention Reporting System at www.iedison.gov.

5.05 Cost Sharing

Cost sharing is permitted for applications under this program FFO; however, cost sharing is not required and will not be considered in evaluation of applications.

5.06 Profit or Fee

A reasonable profit or fee is allowed.

5.07 Joint Ventures or Limited Partnerships

See [13 C.F.R. § 121.103\(h\)](#). Joint ventures and limited partnerships are eligible, provided the entity created qualifies as a small business as defined in this FFO. The awardee may enter into contracts, subawards, or other agreements with universities or other non-profit organizations.

5.08 Research and Analytical Work

For Phase I, a minimum of two-thirds of the research and/or analytical effort, per Section 1.03, must be performed by the proposing SBC. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-third of the total award. For Phase II, a minimum of one-half of the research and/or analytical effort, per Section 1.03, must be performed by the applicant. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-half of the total award.

5.09 Awardee Commitments

Upon award of a funding agreement, the awardee will be required to make certain legal commitments through acceptance of numerous Special Award Conditions (SAC) in the funding agreement. Awards also will be governed by the Department of Commerce Financial Assistance Standard Terms and Conditions (December 2014), Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards at 2 C.F.R. Part 200, adopted by the Commerce Department through 2 C.F.R. § 1327.101; and the DoC Pre-Award Notification Requirements for Grants and Cooperative Agreements, 79 FR 78390 (December 30, 2014);.

Section 5.10 describes the types of terms and conditions to which the awardee would commit. This list is not a complete list of terms and conditions to be included in Phase I and Phase II funding agreements, and is not the specific wording of such terms and conditions.

5.10 Summary Statements

The following statements apply to Phase I and Phase II awards and are examples of some of the topic areas that will be addressed in the award terms and conditions.

(1) Access to Records. Government officials have the right of timely and unrestricted access

to records of awardees, including access to personnel for discussion related to the records. See 2 C.F.R. § 200.336.

(2) Termination. Awards may be terminated (a) by the NIST Grants Officer, if an awardee materially fails to comply with the terms and conditions of an award, or for cause; (b) by the NIST Grants Officer with the consent of the awardee, in which case the two parties shall agree upon the termination conditions, including the effective date and, in the case of partial termination, the portion to be terminated; (c) by the awardee upon sending to the NIST Grants Officer written notification setting forth the reasons for such termination, the effective date, and, in the case of partial termination, the portion to be terminated. See [2 C.F.R. §§ 200.338-342](#).

(3) Non-Discrimination. The awardee will be required to comply with statutory and other non-discrimination requirements. No person in the United States shall, on the ground of race, color, national origin, handicap, age, religion, or sex, be excluded from participation in, be denied the benefits of, or be subject to discrimination under any program or activity receiving Federal financial assistance. See Department of Commerce Financial Assistance Standard Terms and Conditions, Section K.

(4) Audit Requirements. Government officials may conduct an audit of an award at any time. Unless otherwise specified in the award, for-profit organizations that expend \$750,000 or more in Department of Commerce funds during their fiscal year must have an audit conducted for that year in accordance with Subpart F of 2 C.F.R. Part 200. See Department of Commerce Financial Assistance Standard Terms and Conditions, Section F.

(5) Codes of Conduct. Codes of Conduct. Pursuant to the certification in Form SF-424B, paragraph 3, the awardee must maintain written standards of conduct to establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain in the administration of the award. See Department of Commerce Financial Assistance Standard Terms and Conditions, Section J.01.

5.11 Additional Information

If there is any inconsistency between the information contained herein and the terms of any resulting SBIR funding agreement, the terms of the funding agreement are controlling. Before award of a SBIR funding agreement, the Government may request the applicant to submit certain organizational, management, personnel, and financial information to assure responsibility of the applicant.

The Government is not responsible for any funds expended by the applicant before award of any funding agreement.

This program FFO is not an offer by the Government and does not obligate the Government

to make any specific number of awards. Also, awards under the SBIR Program are contingent upon the availability of funds.

The SBIR Program is not a substitute for existing unsolicited application mechanisms. Unsolicited applications will not be accepted under the SBIR Program in either Phase I or Phase II.

If an award is made pursuant to an application submitted under this SBIR Program FFO, a representative of the awardee will be required to certify that the concern has not previously been, nor is currently being, paid for essentially equivalent work by any Federal agency. The responsibility for the performance of the principal investigator, and other employees or consultants who carry out the proposed work, including those of subrecipients or contractors, lies with the management of the organization receiving an award.

NIST is committed to the goal of commercialization of the results of SBIR projects and may provide discretionary technical and commercialization assistance to awardees as allowed by legislation.

5.12 Technical Assistance for Application Preparation and Project Conduct

Applicants may wish to contact the NIST Hollings Manufacturing Extension Partnership (MEP), a nationwide network of locally managed extension centers whose sole purpose is to provide small- and medium-sized manufacturers with the help they need to succeed. The centers provide guidance to high-technology companies seeking resources and teaming relationships. To be referred to an MEP center for technical assistance, call 1-800-MEP-4-MFG (1-800-637-4634) or visit MEP's website at <http://www.nist.gov/mep>.

MEP Centers are also prepared to provide referrals to state and local organizations offering resources and technical assistance to all NIST SBIR applicants after awards have been announced. If you would like your local MEP Center to contact you, please respond affirmatively to the statement (#12) about MEP on the Cover Sheet.

6.0 SUBMISSION OF APPLICATIONS

6.01 Deadline for Applications

Phase I electronic applications must be received no later than 11:59 p.m. Eastern Time, April 14, 2016. Paper applications must be received by NIST by 5:00 p.m. Eastern Time, April 14, 2016.

Electronic applicants should be aware, and factor in their application submission planning,

that the Grants.gov system is expected to be closed for routine maintenance at these times:

from 12:01 a.m. Eastern Time, Saturday, February 20, 2016 until Monday, February 22, 2016 at 6:00 a.m. Eastern Time; and from 12:01 a.m. Eastern Time, Saturday, March 19, 2016 until Monday, March 21, 2016 at 6:00 a.m. Eastern Time, and that applications cannot be submitted during those time spans.

Applicants are cautioned to be careful of unforeseen delays that can cause late arrival of applications, with the result that they **will not** be forwarded for evaluation. For security purposes, applications should not be e-mailed.

Applications not received by the specified due date and time or that do not adhere to the other requirements of this FFO (see Section 4.02 Screening Criteria) will not be considered and will be returned without review. NIST determines whether applications submitted by paper have been received by the deadline by the date and time it was physically received by NIST at its Gaithersburg, MD campus. For electronic submissions, NIST will consider the date and time recorded by www.grants.gov as the official submission time.

NIST strongly recommends that applicants do not wait until the last minute to submit an application. NIST will not make allowance for any late submissions. To avoid any potential processing backlogs due to last minute Grants.gov registrations, applicants are highly encouraged to begin their Grants.gov registration process early.

When developing your submission timeline, please keep in mind that (1) all applicants are required to have a current registration in the System for Award Management (SAM.gov); (2) the free annual registration process in the electronic System for Award Management (SAM.gov) (see Section 6.03.(2).b. of this FFO) may take between three and five business days or as long as more than two weeks; and (3) electronic applicants are required to have a current registration in Grants.gov; and (4) applicants using Grants.gov will receive a series of e-mail messages over a period of up to two business days before learning whether a Federal agency's electronic system has received its application. **Please note that a federal assistance award cannot be issued if the designated recipient's registration in the System for Award Management (SAM.gov) is not current at the time of the award.**

Electronic applicants will find instructions on registering with SAM.gov as part of the Grants.gov process at: <http://www.grants.gov/web/grants/applicants/organization-registration.html>

Paper applicants will find instructions on registering with SAM.gov by going to www.sam.gov and choosing "Create User Account".

6.02 Address to Request Application Package

The standard application package, consisting of the standard forms, i.e., SF-424, SF-424A, SF-424B, SF-LLL, and the CD-511, is available at www.grants.gov. The standard application package may be requested by contacting the NIST personnel listed below:

J'aime Maynard by phone: (301) 975-8408 or by e-mail: jmaynard@nist.gov .

It can also be obtained by writing to:

National Institute of Standards and Technology
NIST SBIR Program Office
Attn: J'aime Maynard
100 Bureau Dr., MS 2200
Gaithersburg, MD 20899

Please see Section 8.01 for a complete list of required forms and documents.

6.03 Application Submission

Applications may be submitted by paper or electronically through Grants.gov.

Supplementary material, revisions, substitutions, audio or video tapes, or computer storage media or devices will **not** be accepted. While applicants may not submit replacement pages or missing documents once an application has been submitted, an applicant may submit a complete, new application including such information by the required deadline.

(1) Paper applications must be submitted to:

National Institute of Standards and Technology
NIST SBIR Program Office
Attn: J'aime Maynard
100 Bureau Dr., MS 2200
Gaithersburg, MD 20899

If hand delivered, 24-hours' notice must be given to the NIST SBIR Program Office prior to delivery. All applicants must contact J'aime Maynard at (301) 975-8408 or jmaynard@nist.gov to arrange hand delivery of application packages. Applications may **not** be dropped off at the NIST Visitor Center. Hand delivery will only be accepted through prior arrangement.

Secure packaging is mandatory. Do not send separate "information copies". Do not use special bindings or covers.

(2) Electronic applications must be submitted via Grants.gov at www.grants.gov, under announcement 2016-NIST-SBIR-01.

a) Submitters of electronic applications should carefully follow specific Grants.gov instructions to ensure the attachments will be accepted by the Grants.gov system. A receipt from Grants.gov indicating an application is received does not provide information about whether attachments have been received. For further information or questions regarding applying electronically for the 2016-NIST-SBIR-01 announcement, contact Christopher Hunton by phone at 301-975-5718 or by e-mail at grants@nist.gov.

b) Applicants are strongly encouraged to start early and not wait until the approaching due date before logging on and reviewing the instructions for submitting an application through Grants.gov. The Grants.gov registration process must be completed before a new registrant can apply electronically. If all goes well, the registration process takes three (3) to five (5) business days. If problems are encountered, the registration process can take up to two (2) weeks or more. Applicants must have a valid unique entity identifier number and must maintain a current registration in the Federal government's primary registrant database, the System for Award Management (<https://www.sam.gov/>), as explained on the Grants.gov Web site. *See also* Section 8.02 of this FFO. After registering, it may take several days or longer from the initial log-on before a new Grants.gov system user can submit an application. Only authorized individuals(s) will be able to submit an application, and the system may need time to process a submitted application. Applicants should save and print the proof of submission they receive from Grants.gov. If problems occur while using Grants.gov, the applicant is advised to (a) print any error message received and (b) call Grants.gov directly for immediate assistance. If calling from within the United States or from a U.S. territory, please call 800-518-4726. If calling from a place other than the United States or a U.S. territory, please call 606-545-5035. Assistance from the Grants.gov Help Desk will be available around the clock every day, with the exception of Federal holidays. Help Desk assistance will resume at 7:00 a.m. Eastern Time the day after Federal holidays. For assistance using Grants.gov, you may also contact support@grants.gov.

c) To find instructions on submitting an application on Grants.gov, Applicants should refer to the "Applicants" tab in the banner just below the top of the www.grants.gov home page. Clicking on the "Applicants" tab produces two exceptionally useful sources of information, Applicant Actions and Applicant Resources, which applicants are advised to review.

Applicants will receive a series of e-mail messages over a period of up to two business days before learning whether a Federal agency's electronic system has received its application. Closely following the detailed information in these subcategories will increase the likelihood of acceptance of the application by the Federal agency's electronic system.

Applicants should pay close attention to the guidance under "Applicant FAQs," as it contains information important to successful submission on Grants.gov, including essential details on the naming conventions for attachments to Grants.gov applications.

The Grants.gov Online Users Guide available at the Grants.gov site (<http://go.usa.gov/cjaEh>) provides vital information on checking the status of applications. See especially the “Check My Application Status” option, found by clicking first on Applicants, and then by clicking on Applicant Actions.

The application must be both received and validated by Grants.gov. The application is “received” when Grants.gov provides the applicant a confirmation of receipt and an application tracking number. If an applicant does not see this confirmation and tracking number, the application has not been received. After the application has been received, it must still be validated. During this process, it may be “validated” or “rejected with errors.” To know whether the application was rejected with errors and the reasons why, the applicant must log in to Grants.gov, select “Applicants” from the top navigation, and select “Track my application” from the drop-down list. If the status is “rejected with errors,” the applicant may still seek to correct the errors and resubmit your application before the deadline. If the applicant does not correct the errors, the application will not be forwarded to NIST by Grants.gov.

NIST uses the Tracking Numbers assigned by Grants.gov, and does not issue Agency Tracking Numbers.

All applicants, both electronic and paper submitters, should be aware that adequate time must be factored into applicants’ schedules for delivery of their application. Submitters of electronic applications are advised that volume on Grants.gov may be extremely heavy leading up to the deadline date, and if Grants.gov is unable to accept applications electronically in a timely fashion, applicants are encouraged to exercise their option to submit applications in paper format. Submitters of paper applications should allow adequate time to ensure a paper application will be received on time, taking into account that Federal Government security screening for U.S. Postal Service mail may delay receipt of mail for up to two (2) weeks and that guaranteed express mailings and/or couriers are not always able to fulfill their guarantees.

Refer to important information in Section 6.01 Deadline for Applications, to help ensure your application is received on time.

Any amendments to this FFO will be announced through Grants.gov. Applicants can sign up for Grants.gov FFO amendments or may request copies from J’aime Maynard by telephone at (301) 975-8408, or by email to jmaynard@nist.gov.

Applicants are advised to check the public Question and Answer website located at <http://www.nist.gov/sbir> for up-to-date information concerning specific subtopics that may be posted during the FFO open period.

7.0 SCIENTIFIC AND TECHNICAL INFORMATION SOURCES

Background information related to the NIST research programs referenced within the subtopics may be found within the NIST website at: www.nist.gov. The NIST Virtual Library, <http://nvl.nist.gov/> may also provide valuable scientific and technical information resources. Wherever possible, reference citations are provided within the individual subtopics.

8.0 SUBMISSION FORMS AND CERTIFICATIONS

8.01 Required Forms and Documents

A complete application contains the Technical Proposal elements described in Section 3.02 and the following forms and documents:

(1) SF-424, Application for Federal Assistance. The SF-424 must be signed by an authorized representative of the applicant organization.

SF-424, Item 12, should list the FFO number 2016-NIST-SBIR-01.

For SF-424, Item 21, the list of certifications and assurances is contained in the SF-424B.

(2) SF-424A, Budget Information – Non-Construction Programs. The Grant Program Function or Activity on Line 1 under Column (a) should be entered as Science, Technology, Business and/or Education Outreach. The Catalog of Federal Domestic Assistance Number in on Line 1 under Column (b) should be entered as 11.620.

(3) SF-424B, Assurances - Non-Construction Programs.

(4) CD-511, Certification Regarding Lobbying.

(5) SF-LLL, Disclosure of Lobbying Activities (if applicable).

(6) Technical Proposal, including forms and documents described in Section 3.02 of this FFO. Be sure to read all of Section 3.02 very carefully. Use the Cover Sheet found in Appendix A of this FFO as pages 1 and 2 of the Technical Proposal, and follow the guidance regarding the Technical Content.

(7) Budget Narrative. There is no set format for the Budget Narrative; however, it should provide a detailed breakdown of each of the object class categories as reflected on the SF-424A. Provide enough information to allow NIST to understand how funds will be used and clearly demonstrate that proposed costs fall within the spending limitations specified in Section 1.03 of this FFO (For Phase I, a minimum of two-thirds of the

research and/or analytical effort must be performed by the awardee. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-third of the total award. For Phase II, a minimum of one-half of the research and/or analytical effort, per Section 1.03, must be performed by the applicant. The total cost for all consultant fees, facility leases, usage fees, and other subcontract/subaward or purchase agreements may not exceed one-half of the total award.)

The proposed budget should reflect planned costs, but the awardee must charge actual costs to the award consistent with cost principles applicable to the type of awardee in accordance with the Uniform Administrative Requirements, Cost Principles, and Audit Requirements for Federal Awards at 2 C.F.R. Part 200, which apply to awards in this program. More information is available at <http://go.usa.gov/SBYh> and <http://go.usa.gov/SBg4>. The awardee should have an accounting system that tracks costs per SBIR firm and an allocation plan for activities that may be shared among multiple SBIR firms.

(8) Indirect Cost Rate Agreement. NIST will not negotiate indirect cost rates for Phase I awards. If indirect costs are included in the proposed budget, provide a copy of the current, approved negotiated agreement if this rate was negotiated with a cognizant Federal audit agency. If a rate has not been established, provide a statement to this effect. Applicants without an established rate, may propose estimated indirect costs at a rate not to exceed 40 percent of the total direct costs and will not be required to provide further justification if selected for an award.

(9) SBA Company Registry Form. SBA maintains and manages a Company Registry at <http://www.sbir.gov/registration> to track ownership and affiliation requirements for all companies applying to the SBIR Program. The SBIR Policy Directive requires each Phase I and Phase II applicant to register in the Company Registry prior to submitting an application. The applicant must save its information from the registration in a .pdf document and attach this document to the SF-424 as described below.

(10) Data Management Plan. In accordance with the Office of Science and Technology Memorandum for the Heads of Executive Departments and Agencies of February 22, 2013¹, *Increasing Access to the Results of Federally Funded Scientific Research*, and as implemented through NIST Policy 5700.00², *Managing Public Access to Results of Federally Funded Research*, and NIST Order 5701.00³, *Managing Public Access to Results of Federally Funded Research*, applicants should include a Data Management Plan (DMP).

¹ https://www.whitehouse.gov/sites/default/files/microsites/ostp/ostp_public_access_memo_2013.pdf

² <http://www.nist.gov/open/upload/Final-P-5700.pdf>

³ http://www.nist.gov/open/upload/Final-O-5701_0.pdf

The DMP is a supplementary document of not more than two pages that must include, at a minimum, a summary of proposed activities that are expected to generate data, a summary of the types of data expected to be generated by the identified activities, a plan for storage and maintenance of the data expected to be generated by the identified activities, and a plan describing whether and how data generated by the identified activities will be reviewed and made available to the public. As long as the DMP meets these NIST requirements, it may take the form specified by the applicant's institution or some other entity (e.g., the National Science Foundation⁴ or the National Institutes of Health⁵). Some organizations' templates are available on the Internet⁶.

All applications for activities that will generate scientific data using NIST funding are required to adhere to a DMP or explain why data sharing and/or preservation are not within the scope of the project.

For the purposes of the DMP, NIST adopted the definition of "research data" at 2 C.F.R. § 200.315(e)(3) (available at <http://go.usa.gov/3sZvQ>)

Reasonable costs for data preservation and access may be included in the application.

The sufficiency of the DMP will be considered as part of the administrative review (see Section 4.02. of this FFO); however, the DMP will not be evaluated against any evaluation criteria.

If submitting the application electronically via Grants.gov, items (1) through (5) above are part of the standard application package in Grants.gov and can be completed through the download application process. **Items (6) through (10) must be completed and attached by clicking on "Add Attachments" found in item 15 of the SF-424, Application for Federal Assistance. This will create a zip file that allows for transmittal of the documents electronically via Grants.gov.** Applicants should carefully follow specific Grants.gov instructions at www.grants.gov to ensure the attachments will be accepted by the Grants.gov system. **A receipt from Grants.gov indicating an application is received does not provide information about whether attachments have been received.**

If submitting an application by paper, all of the required application documents should be submitted in the order listed above.

8.02 Unique Entity Identifier and System for Award Management (SAM)

Pursuant to 2 C.F.R. Part 25, applicants and recipients (as the case may be) are required to: (i) be registered in SAM before submitting its application; (ii) provide a valid unique entity

⁴ <http://www.nsf.gov/bfa/dias/policy/dmp.jsp>

⁵ http://grants.nih.gov/grants/policy/data_sharing/data_sharing_guidance.htm#inc

⁶ <https://www.cic.net/projects/technology/shared-storage-services/data-management-plans>

identifier in its application; and (iii) continue to maintain an active SAM registration with current information at all times during which it has an active Federal award or an application or plan under consideration by a Federal awarding agency, unless otherwise excepted from these requirements pursuant to 2 C.F.R. § 25.110. NIST will not make a Federal award to an applicant until the applicant has complied with all applicable unique entity identifier and SAM requirements and, if an applicant has not fully complied with the requirements by the time that NIST is ready to make a Federal award pursuant to this FFO, NIST may determine that the applicant is not qualified to receive a Federal award and use that determination as a basis for making a Federal award to another applicant.

9.0 RESEARCH TOPIC AREAS

The research topic areas that will be supported by NIST's SBIR program are those aligned with NIST's investment priority areas identified in NIST's Three-Year Programmatic Plan: <http://www.nist.gov/director/planning/planning.cfm>.

9.01 Advanced Sensing for Manufacturing

9.01.01 Absolute Interferometry with Nanometer Precision

Absolute length metrology with improved repeatability and uncertainty is needed for advanced manufacturing and other applications including coordinate measuring machine/computer numerical control (CMM/CNC) calibration and positioning [1], laser materials processing, medical materials quality assurance, gauge block calibration, and optical and UV metrology of free-form optics [2,3]. There is also a need in some metrology systems, including atomic force microscopes (AFM) [4] and scanning electron microscopes (SEM), to measure the drift in stage or probe-related components relative to the metrology loop of the instrument. Absolute interferometry can remove the ambiguity of classical interferometry without the need for continuous monitoring of a displacement. Specialize research needs can benefit from absolute distance measurement with nanometer-level accuracy. In a commercial setting, classical interferometry cannot satisfy the need for tasks such as measuring rough or high-relief surfaces, discontinuous steps, reflections from multiple interfaces, or thickness measurement; absolute interferometry potentially can overcome all of these limitations.

The goal is affordable, accurate, and rapid absolute interferometric length measurement with improved repeatability and uncertainty, for precision measurement or research applications. Desired is development of an instrument that can absolutely measure the distance between two parallel surfaces with resolution and accuracy as high as possible—better than 10 nm for measuring short lengths and better than 1 part in 10^7 for longer lengths (ideally up to 500 mm) exclusive of uncertainties associated with air refractive index (i.e., it should be better than 1 part in 10^7 measuring a separation in vacuum). The parallel surfaces may be pointing in the same direction but laterally separated (such as a gage block

measurement) or might be facing each other but made of transparent material allowing transmission of a laser beam, as in the case of optical thickness measurement. Measurement update rates should exceed 1 kHz. For metrology of rough surfaces, such as many unpolished metals, the repeatability and uncertainty should approach the material surface roughness. Moreover, the solution should be able to achieve specification from both shiny and dull surfaces, should be able to achieve diffraction limited lateral resolution, and should be able to accommodate co-alignment with a processing beam for cases such as laser materials processing (welding, drilling, cutting).

Phase I expected results:

Experimentally prove the feasibility of a non-contact length metrology system that can provide measurement repeatability and expanded uncertainty better than $10 \text{ nm} + 1 \times 10^{-7} * L$, where L is the measured length (surface separation) up to 500 mm, at $>1 \text{ kHz}$ update rates, exclusive of uncertainties associated with air refractive index. The system should be able to also measure non-specular surfaces to within approximately the surface roughness.

Phase II expected results:

Design, construct, and demonstrate a prototype of the non-contact length metrology system for which the feasibility was proven in Phase I.

NIST staff will be available for consultation, input, and discussion.

References:

[1] http://www.nist.gov/pml/div683/grp01/dmg_cst.cfm.

[2] DeFisher, S., Bechtold, M. and Mohring, D. "A Non-Contact Surface Measurement System for Freeform and Conformal Optics", Proc. SPIE 2011, Volume 8016, paper 80160W.

[3] <http://www.nist.gov/pml/div683/grp02/osmns.cfm>.

[4] <http://www.nist.gov/pml/div683/grp02/cafm>.

9.01.02-R Design of fiber-coupled waveguide difference frequency generation devices

NIST seeks to determine the technical feasibility of fiber-coupled waveguide devices for the highly efficient ($\geq 10\% W^{-1}$) difference frequency generation (DFG) of mid-infrared laser radiation. The proposed compact photonic device would enable the deployment of optical sensors that operate in the important "molecular fingerprint" region of the electromagnetic spectrum (3000-5000 nm) thus meeting present and future demands for air-quality monitoring, gas metrology, and atmospheric monitoring. The demonstration of highly efficient fiber-coupled waveguide devices for frequency conversion, specifically at a wavelength $\approx 4500 \text{ nm}$, would allow the transfer of mature frequency-agile rapid scanning technology from the telecommunication bands into the mid-infrared where strong

molecular transitions promise ultrasensitive detection limits. Compact mid-infrared optical sensors with frequency agility would be of great interest to various stakeholders within the U.S. gas sensors market, which is expected to increase to \$550 million by 2018 [1].

The goal of this subtopic is to determine the technical feasibility of fiber-coupled waveguide devices for highly efficient DFG of mid-infrared radiation through proof-of-concept demonstrations. The frequency conversion process performed by these proposed devices should create an output photon with frequency $f_{\text{out}} = f_1 - f_2$, where f_1 and f_2 are unique input laser frequencies in the near-infrared. Specifically, NIST seeks to determine the feasibility of a waveguide device capable of creating free-space continuous-wave (cw) radiation at an output wavelength of 4530 nm from the combined fiber-coupled input of cw lasers operating at 1572 and 1167 nm, respectively. Beyond a fiber-coupled waveguide device for DFG of coherent 4530 nm radiation, NIST has identified a long-term need for fiber-coupled waveguide devices (either narrowband or broadly tunable) that cover the entire mid-infrared region from 3000-5000 nm.

Phase I expected results:

Report on the feasibility and design of a proof-of-concept fiber-coupled waveguide device for DFG with $\geq 10\% W^{-1}$ conversion efficiency.

Phase II expected results:

Construct prototype waveguide devices and demonstrate their highest achievable conversion efficiency at an output wavelength of 4530 nm.

NIST may be available to provide technical guidance, work collaboratively on design concepts, discuss goals, and to aid in prototype evaluation.

Reference:

[1] Research and Markets: "U.S. Gas Sensors Market 2015-2020 - Growth, Trends & Forecasts for \$550 Million Industry", *Reuters* Press Release, June 10, 2015.

9.01.03 High-Accuracy Angle Generator for Precision Measurements

More accurate angle generators would allow NIST and other metrology laboratories to lower uncertainty in high-precision angle measurements. These generators would provide a needed tool for NIST and other world leading metrology laboratories to understand how surface flatness affects the measurement of angle using autocollimators, which is the de-facto tool for high accuracy angle measurements at NIST. These effects are the limiting uncertainty component in angle measurements that support R&D in critical technology intensive sectors.

X-ray studies at synchrotron light sources of the atomic structure of materials, biological molecules, etc. are currently limited by the quality of the x-ray spot focused onto the specimen. The quality of the focused spot is determined by the form accuracy of the mirrors

used to focus the beam, typically a pair of elliptically-shaped mirrors used at grazing incidence. Improvements to the form accuracy of these mirrors are limited by the current abilities of metrology techniques. Specifically, improvements to the measurement of the local surface slope are needed. Metrologists at these synchrotron light sources are now using an autocollimator-based scanning technique to measure the surface profile for large (up to 1.5 m length), curved mirrors [1,2]. Effects of the curvature of the surface under test on the accuracy of the autocollimator used to measure the local surface slope need to be characterized to achieve the required tolerances of the mirrors.

Next-generation photonic devices incorporate various components whose geometry must be well characterized. NIST is currently measuring the angular attributes of these artifacts for industrial customers using autocollimators. Uncertainty components due to non-flat surface for these measurements are not well understood and published reports in this area are not exhaustive [3].

The goal is to develop precision angle generators that have accuracies that are better than what is currently commercially available. It is desired that the angle generator be able to accommodate mirrors with clear apertures between 2 mm and 35 mm that are up to 300 mm × 50 mm × 50 mm in size (i.e., approximate size of curved mirrors used at synchrotron light sources).

Phase I expected results:

Experimentally prove the feasibility of fabricating an angle generator with an expanded uncertainty ($k=2$) of less than 0.01 arc-seconds over an angular range of 2.5 degrees.

Phase II expected results:

Provide a prototype automated precision angle generator with a rigorously documented uncertainty budget demonstrating that the target uncertainty requirements, an expanded uncertainty ($k=2$) of less than 0.01 arc-seconds over an angular range of 2.5 degrees, are met.

NIST will be available for consultation and collaboration as necessary.

References:

[1] Geckeler, R.D., Just, A., Krause M. and Yashchuk, V.V. "Autocollimators for deflectometry: Current status and future progress", Nucl. Instrum. Methods Phys. Res. A **616** (2010) 140–146.

[2] Yandayan, T., Geckeler, R.D. and Siewert, F. "Pushing the limits – latest developments in angle metrology for the inspection of ultra-precise synchrotron optics", Proc. SPIE 9206, Advances in Metrology for X-Ray and EUV Optics V, 92060F (2014).

[3] Kruger, O.A. "Methods for determining the effect of flatness deviations, eccentricity and

pyramidal errors on angle measurements”, *Metrologia* **37** (2000) 101–105.

9.01.04 High-Density Cryogenic Probe Station

Electrical probe stations are ubiquitous tools in the semiconductor electronics and data storage industries [1-6]. These instruments enable the probing of electrical properties of microfabricated electronics on silicon wafers or other planar substrates. This probing is used to determine whether the microfabrication was successful; if so, the silicon wafers are then cut into smaller pieces called dies that are packaged and integrated into more complex electronic assemblies. Typically, a silicon substrate contains many identical die so the electrical probes are translated over the substrate, aligned to the relevant features, placed in contact with the substrate, used for measurements, and then translated to the next die location. Probe station technology is well developed for electronics that function at room temperature. In particular, so-called probe cards allow a large number (hundreds) of temporary electrical connections to be made to a substrate using only mechanical pressure. However, there is an unmet need for a probe station with numerous closely packed electrical probes that can operate at temperatures near 4 K.

In recent years, the need for and variety of electronics that operate at temperatures near 4 K have expanded greatly. Examples include sensors for industrial materials analysis, nuclear security, concealed weapons detection, and astrophysics. The next generation of instruments to study the cosmic microwave background, for instance, may require 10s to 100s of silicon wafers containing cryogenic circuitry. Another example is classical computing using high speed, low power superconducting elements. Still another example is quantum computing using novel circuit components also based on superconducting films. Both research and commercial activity based on cryogenic electronics are growing. In order to aid the manufacture of cryogenic electronics, NIST is soliciting proposals for the development of a probe station optimized for this emerging market area.

Cryogenic electronics must be tested at low temperatures near their planned operating temperatures. Testing after microfabrication but before dicing and integration can save manufacturers and customers the enormous expense of packaging, shipping, cooling, and attempting to use flawed electronic components.

While cryogenic probe stations are already commercially available, these units do not have performance suitable for emerging applications. For example, niobium is a crucial material in cryogenic superconducting electronics. The transition temperature of niobium is 9.2 K and devices containing niobium must be probed at temperatures well below this value in order for the tests to accurately predict device behavior. Hence, the silicon substrate being tested should be at a temperature near 4.2 K or colder. Existing cryogenic probe stations are not able to achieve temperatures this low for the large substrates (up to 150 mm in diameter) that are now used to make superconducting circuits. As the complexity of cryogenic electronics has increased, so too has the number of circuit elements that need to

be probed on a single die. However, existing cryogenic probe stations have only small numbers of probes (typically less than 10) that are physically large and therefore cannot be used to contact the closely spaced features that are increasingly used in cryogenic electronics. Further, existing probes are often optimized for much higher signal bandwidth than is now needed for basic tests of circuit functionality. Finally, these probes often contact the substrate under test from a warmer temperature stage and therefore are a major heat load that makes temperatures near 4.2 K difficult or impossible to achieve.

To aid the manufacture of cryogenic electronics for sensing and computing, NIST seeks proposals for a high-density cryogenic probe station that meets the following technical goals:

- Sample cooling to 4.5 K or below. This value refers to the temperature of the substrate under test and not the temperature of the underlying metal. Use of a mechanical cryocooler is preferred but liquid or gaseous helium are also acceptable.
- Rapid cooling and warming are desirable. A cool-down time from 300 K to base temperature below 2 hours is preferred. A warm-up time from base temperature to 300 K below 1 hour is preferred.
- Compatibility with substrates up to 150 mm in diameter.
- The ability to simultaneously make 100 or more electrical contacts to a die under test. Contacts to be made using mechanical pressure only, not wirebonding or other contact schemes that mechanically alter the test substrate.
- Electrical contacts must be pre-cooled at the cold stage of the probe station before contacting the substrate under test so as to preserve a sample temperature below 4.5 K.
- Electrical contacts should be low resistance with a best-effort goal of 10 milliOhm contact resistances.
- Electrical contacts should also be high-density with a best-effort goal of center-to-center pitches as small as 150 μm . Metallic contact features on the substrate are expected to be as small as 100 μm in diameter. The mechanical pattern of the contacts can be fixed so long as it is reconfigurable via use of alternate probe cards.
- Electrical contacts to be compatible with signal bandwidths below 500 kHz.
- Mechanical provisions to move the electrical contacts over the complete substrate under test while cold in order to probe multiple identical contact patterns on the substrate.
- Optical or other provisions to align the electrical connections to the contact pattern on the substrate.
- Provisions at room temperature to perform basic electrical measurements (continuity, current-voltage curves, etc.) among any combination of the electrical contacts.

Phase I expected results:

Develop a mechanical and electrical design that addresses the project goals described above.

Phase II expected results:

Construct a prototype high-density cryogenic probe station that is able to achieve the project goals described above.

NIST personnel will be available to assist the awardee in a variety of ways, including but not limited to:

- consulting on instrument design including participation in design reviews,
- sharing the results of NIST research to develop high-density probe cards suitable for cryogenic applications, including prototypes, with the awardee, and
- fabricating and providing at no cost substrates up to 150 mm in diameter with metal test patterns that can be used by the awardee to demonstrate cryogenic probing.

References:

[1] Applications for superconducting electronics:

<http://www.scientificcomputing.com/news/2014/12/iarpa-develop-superconducting-supercomputer>.

[2] <http://arxiv.org/pdf/1309.5383v3.pdf> (for the motivation for arrays of 500,000 superconducting sensors).

[3] Examples of existing cryogenic probe stations:

<http://www.lakeshore.com/products/cryogenic-probe-stations/pages/cryogenic-probe-stations.aspx>.

[4] Micro-manipulated Cryogenic & Vacuum Probe Systems for Chips, Wafers and Device Testing from ~3.5 K to 675 K,

http://www.janis.com/ProbeStations_Home_KeySupplier.aspx.

[5] Examples of existing high-density probe cards for room temperature operation:

<https://www.cmicro.com/products/probe-cards>.

[6] Cantilever Probe Cards - Well Beyond the State of the Art,

<http://www.technoprobe.com/cantilever-probe-card/>.

Any mention of commercial products is for information only; it does not imply recommendation or endorsement by NIST.

9.01.05 High Temperature *In Situ* Pressure Sensor

There is a need to measure pressure accurately. Chemical manufacturers need process sensors that are able to monitor changes in manufacturing systems. These systems need to have a low uncertainty and high sensitivity to change. Often accurate pressure measurements in the chemical manufacturing industry are necessary to keep

manufacturing processes safe. Sometimes, these changes affect other parameters, such as a flow measurement, and are necessary to maintain good manufacturing processes. At NIST, the need for highly accurate pressure measurements is prominent when determining the thermophysical properties of fluids, especially because these measurements lead to the development of theoretical models for industry. NIST researchers have developed methods to achieve better-than-quoted uncertainty in today's pressure transducers through good practices, but the market is still limited. In order to meet the high standards NIST has for metrology measurements, we seek a high temperature *in situ* pressure sensor that achieves better resolution than the current pressure transducers available today.

The goal of this SBIR subtopic is to develop an *in situ* pressure sensor for fluid systems that operate up to 200 °C and pressures up to 7 MPa. Here, "in situ" means that the sensor is either attached directly to the system being measured (e.g., attached to a standard pipe fitting) or in very close proximity to the system; in either case it would be at the same temperature as the system. The sensor shall have remarkable temperature stability, control over drift, a small wetted volume (less than 5 mL), and be manufactured from materials that are highly corrosion resistant. On the market today, there are sensors that can reach the desired temperature of 200 °C, but these sensors often have large volumes or high uncertainty. The desired pressure sensor is expected to have a small volume to allow for easy coupling to a variety of precision measurement systems at NIST [1,2] as well as being able to act as a sensor in the chemical industries.

NIST envisions at least two basic design approaches, and either would be acceptable, as would other proposed designs. In the first approach, the sensor would directly measure the pressure and transmit a signal to a control computer. In the second basic approach, the sensor would measure the *difference* between the pressure of the fluid system and a reference pressure. In this embodiment, the reference pressure would be that of an inert gas or a hydraulic fluid, which would then be measured by a conventional pressure sensor that would be located remotely, e.g., at ambient temperature.

NIST is interested in a system with the following performance metrics:

- The pressure sensor shall operate in thermostated conditions of –70 °C to 200 °C.
- The pressure measurement must reach equilibrium in a reasonable time (< 5 minutes).
- The uncertainty in pressure must be better or equal in pressure to current pressure transducers, i.e., 0.7 kPa or 0.01% of range. The uncertainty shall include all effects, including hysteresis with increasing or decreasing pressures, compensation for temperature over the full operating range, and drift in the zero point.
- The measurement pressure range shall be ambient up to 7 MPa. The sensor shall provide a direct pressure measurement up to 7 MPa or be able to withstand differential pressures up to 7 MPa (if a differential pressure measurement).
- Electronic signals (both raw signals and computed pressure) shall be accessible to the user through a standard interface (e.g., USB, IEEE-488, or RS-232).

- Any electronic coupling within the thermostated area (*i.e.*, wiring, connectors) shall be temperature compatible up to 200 °C. Other components (such as read-out electronics) may operate at room temperature.
- All wetted parts of the sensor shall be fabricated of corrosion-resistant materials.
- The sensor should be able to be calibrated and maintain its calibration with minimal drift. It is desired that NIST scientists should be able to calibrate it at regular intervals.
- Drift: The sensor must meet the uncertainty specification with calibration intervals of no more than 4 months.
- Hysteresis: Any hysteresis associated with changes in temperature or pressure must fall within the overall uncertainty specification.
- The internal volume shall be less than 5 mL.
- The overall size of the sensor within the thermostated zone shall be 1 L or less. Electronics, however, may reside outside of this area.

Phase I expected results:

Provide a complete design of the pressure sensor. It is expected that CAD drawings of the sensor will be produced. It is also expected that theory and calculations relevant to the sensor function will be explained and provided. The awardee shall address their expected values for each one of the metrics above and describe how they designed their sensor to meet them in their final report for Phase I.

Phase II expected results:

Construct a fully-functional, tested prototype. The prototype shall be cycled over the full range of temperature and pressure at least 10 times to demonstrate the stability and performance metrics and the data from these tests shall be provided. Documentation on drift, stability and chemical stability shall also be made available. Each metric in the bulleted list above must be measured and addressed. The prototype will be made available to NIST for testing prior to the end of the SBIR Phase II award.

NIST staff is willing to participate in discussions and provide input on the awardee's design during the development process through email, teleconference or face-to-face visits. NIST is also willing to do testing, although the awardee will not be able to count this testing towards the testing requirements of Phase II. NIST scientists may be available for demonstration of the device at the awardee's home site, if desired.

References:

[1] Outcalt, S. L. and Lee, B.-C. "A Small-Volume Apparatus for the Measurement of Phase Equilibria", *J. Res. Natl. Inst. Stand. Technol.* 2004, 109 (6), 525–531.

[2] McLinden, M. O. and Lösch-Will, C. "Apparatus for wide ranging, high-accuracy fluid (p , ρ , T) measurements based on a compact two-sinker densimeter", *J. Chem. Thermodyn.* 2007, 39, 507-530.

9.01.06 Iron Corrosion Detection Technology Using THz Waves: A field-operable Unit Based on NIST Spectroscopic Technology

Corrosion of steel cost the U.S. several \$100B per year. Early detection of this corrosion, most of which is buried under some kind of protective coating like concrete or polymers, would reduce this remediation cost and improve the safety of infrastructure and factories. Current detection methods cannot sense a particular corrosion product, only the presence of something, and especially at early stages when not much corrosion is present. NIST had a Corrosion Detection Innovative Measurement Science project from 2010-2014, in which a 0.1-1 THz wave technology based on antiferromagnetic resonance detection was successfully developed. Two of the most common iron corrosion products, hematite and goethite, are antiferromagnetic, and thus can be detected by this method: hematite through several centimeters of concrete and goethite through polymer layers. This laboratory-based technology needs to be taken to the field in order to have practical commercial use. From talking to government and industry, there is certainly a large need for this technology and apparently a large commercial market exists, too. NIST desires to see this technology commercialized, which involves some technical challenges in translating the laboratory technology into the field.

The goal of this project is to demonstrate a field-operable measurement system, using 0.1 - 1 THz waves, that identifies the presence of the iron corrosion compounds hematite and goethite under a variety of protective coverings, including concrete (hematite) and polymers (hematite and goethite). NIST has demonstrated this technology in the laboratory – the goal is to be able to move this technology into the field for application to corrosion detection problems in factories and physical infrastructure. To be able to detect specific iron corrosion products through protective barriers is an unmet need in the US.

Phase I expected results:

Demonstrate the feasibility of taking the laboratory-based technology to the field, with identification of the technical problems that need to be solved and the current equipment that is available for doing so. A plan for how the field equipment would be operated and a list of sample applications is part of the Phase I expected results.

Phase II expected results:

Demonstrate, in the field and on an important application, of a portable antiferromagnetic resonance –based THz system for corrosion detection of hematite and goethite. This system should be capable of being commercialized.

NIST may be available to provide technical guidance, comments and advice on design concepts, discussion of technical problems, and previous lab data.

References:

[1] Cornell, R.M. and Schwertmann, U. *The Iron Oxides: Structure, Properties, Reactions, Occurrences, and Uses*, 2nd ed., Wiley-VCH GmbH and Co. KGaA (2000). Wiley On-line library.

[2] Kim, S., Surek, J., and Baker-Jarvis, J. "Electromagnetic Metrology on Concrete and Corrosion", *J. Res. Natl. Inst. Stand. Technol.*, 116, 655-669 (2011).

9.01.07 Object Identification and Localization via Non-Contact Sensing for Enhancing Robotic Systems in Manufacturing Operations

This project seeks to advance new low-cost, non-contact sensing technologies for identifying and localizing manufactured-part types of objects to improve the adaptability and ease of use of robots in manufacturing. Quantitative assessment of system performance is an essential project component.

Robots are expensive and complex. With steep learning curves and high adoption costs, small- and medium-sized enterprises (SMEs), which account for 98% of all manufacturing entities, find it difficult to justify their inclusion in everyday operations. Despite this difficulty, robot installations are expected to increase by 12% on average per year between 2015 and 2017. This sustained increase in adoption is expected to occur principally in the automotive, electronics, and materials sectors, where manufacturing applications involve structured environments with high-volume throughput and low mixtures or variations of parts. However, the International Federation of Robotics states that future product life-cycles will decrease alongside an increase in product variety. Unfortunately, the cost of automation is expected to grow exponentially in these low-volume, high-mixture part environments. Therefore, the new era of factory automation requires the adoption of a different technological paradigm where robotic systems can quickly adapt and reconfigure for high variations in parts. Many key technologies are required to unlock these desirable qualities in robotic systems including "human-like" dexterity and robust perception. This topic focuses on robust perception technology for part identification and localization [1-7]. A cornerstone of robot adaptability is perception. Like people, robots need to see and locate parts in the environment to efficiently interact with them. Using expensive tooling, current high-volume manufacturing robots operate under the assumption that parts are predictably placed, and therefore the robot does not need to perceive the object. This automation structure is counterpoint to environments with low-volume, high mixture parts, where automatic part-finding capabilities using non-contact sensing such as cameras and laser scanners become necessary. To adapt, robots need to quickly and accurately identify and locate parts in their environment so that they can make informed operational decisions.

Despite much progress, robotic object perception has yet to reach capability levels that are both robust and easy-to-use. Seamless integration necessitates a perception system capable of variable part identification and localization in six degree-of-freedom Cartesian space without the aid of reference markers or other specialized indicators in the environment. However, use of Computer Aided Design (CAD) model data is justifiable since all parts are

assumed known in a manufacturing environment. These perception systems should leverage calibration and registration techniques that are conducive to the re-configurable and re-tasking environments associated with SMEs. Moreover, the solution must be comparatively low-cost, using commercial off-the-shelf hardware to make perception solutions easily accessible for SMEs. Finally, the system should be robust to lighting conditions, surface properties, part geometries, and occlusions. Performance levels should be reported using clear and concise verification and validation metrics and methodologies. Given that these specifications can be met, robot perception would help reduce integration costs, yielding conditions for improving adoption rates by SMEs.

The goals for this project are three-fold: 1) develop a non-contact perception technology, conducive to the reconfigurable and frequently re-tasked environments associated with SMEs, that is capable of identifying and localizing a variety of part types (e.g. spheres, cuboids, prisms, cylinders, gears, fasteners, hand tools) in six degrees of freedom (leveraging part CAD data to improve system performance is acceptable), 2) benchmark the performance measurement of said technology under a formal approach such as ASTM E2919-14 “Standard Test Method for Evaluating the Performance of Systems that Measure Static, Six Degrees of Freedom (6DOF) Pose,” and 3) work with NIST in constructing new test methods to benchmark robotic system performance for smart manufacturing using the developed perception technology.

NIST is currently developing test methods and metrics for measuring robot system performance in next-generation manufacturing environments. Meeting these project goals will foster innovation in robot perception and aid in the development of performance tests by applying state-of-the-art technology to challenging, dynamic manufacturing operations.

Phase I expected results:

Develop a prototypical non-contact perception technology for identifying and localizing parts with a methodical documentation of performance and conditions (e.g. ASTM E2919-14).

Phase II expected results:

Demonstrate honing perception performance, and provide the necessary tools for simplifying its integration and ease-of-use for non-expert commercial SME users. Develop task-level metrics and test methods with application to empirically convey the performance and significance of perception in SME environments. Demonstrate a hardened product ready for adoption by industry and commercialization in the marketplace.

NIST will be available to work collaboratively, exercising expertise in the modularity and re-tasking requirements of SMEs and measurement science for perception systems to ensure successful completion of project goals.

References:

[1] ASTM E2919-14 “Standard Test Method for Evaluating the Performance of Systems that

Measure Static, Six Degrees of Freedom (6DOF) Pose”, [Available from: <http://www.astm.org/Standards/E2919.htm>].

[2] Falco, J., Marvel, J. and Messina, E. “Dexterous Manipulation for Manufacturing Applications Workshop”, NISTIR 7940, June 2013.

[3] International Federation of Robotics, *Industrial Robot Statistics*, 2014. [cited: 2015, Available from: <http://www.ifr.org/industrial-robots/statistics/>].

[4] Marvel, J., Messina, E., Antonishek, B., Van Wyk, K. and Fronczek, J, “Tools for Robotics in SME Workcells: Challenges and Approaches for Calibration and Registration”, NISTIR, under review.

[5] Computing Community Consortium, *Workshop on Opportunities in Robotics, Automation, and Computer Science*, 2014.

[6] Barajas, L.G., Thomaz, A.L. and Christensen, H.I. “Ushering in the Next Generation of Factory Robotics and Automation”, in *National Workshop on Challenge to Innovation in Advanced Manufacturing: Industry Drivers and R&D Needs*, 2009.

[7] Knight, W. “Increasingly, robots of all sizes are human workmates”, in *MIT Technology Review*, 2014.

9.01.08 Pre-Concentration Technology for Analysis of Halocarbon Gases at Trace Levels

Halocarbons are widely used in manufacturing of semiconductor and related nanoscale devices. These compounds are also greenhouse gases that can contribute significantly to warming of the atmosphere. Although emitted to the atmosphere from manufacturing processes in relatively small quantities, fluorinated halocarbon gases contribute approximately 3% of the approximately 6,670 million metric tons of greenhouse gases emitted to the atmosphere.

Effective measurement of these gases in the atmosphere is a measurement challenge due to their very low concentrations, typically in the picomole/mole or lower concentration region. In recent years there have been major advances in instrumental methods to measure the concentrations and isotopic compositions of the fluorinated gases in air and in other gaseous media by optical (e.g. cavity ring-down spectroscopy, Fourier transform infrared spectroscopy), mass-spectrometric (e.g. quadrupole, magnetic sector, time-of-flight) and other types of detection methods. Full advantage of these measurement advances can be significantly improved through sample pre-concentration prior to introduction to the measuring instrument of choice. In some cases separation from interfering compounds can also be accomplished in the pre-concentration step, significantly improving detection and quantification capabilities. Sample pre-concentration enables

detection and measurement of fluorinated gases present in the atmosphere at concentration levels that are difficult to realize currently, picomole/mole and below levels, and over collection times that can facilitate the emission source identification and estimation of the quantity released.

The goal of this project for atmospheric monitoring applications is to demonstrate a fieldable prototype pre-concentration methodology for fluorinated gases used in the manufacture of advanced devices suitable for application with commercially available technologies, e.g., quadrupole mass spectrometry or similar, for 20 or more gases at the 1 picomole/mole level or below.

Phase I expected results:

Demonstrate a laboratory prototype capability for at least 5 fluorinated gases having detection limits of 10 picomole/mole or below.

Phase II expected results:

Demonstrate a fieldable pre-concentration prototype in an atmospheric monitoring setting using a commercially-available quadrupole mass spectrometer for 20 or more fluorinated gases at a detection limit of 1 picomole/mole or below for at least half of these trace gases sampled from the atmosphere.

NIST may be available to provide advice concerning various types of expertise available at NIST, e.g., NIST expertise in advanced refrigeration technologies likely to be used by any pre-concentration approach.

Reference:

EPA. 2011. U.S. Greenhouse Gas Inventory, <http://www3.epa.gov/climatechange/ghgemissions/gases.html>.

9.01.09 Quantitative Magnetometry of Single Nanoparticles with High Throughput

Magnetic nanoparticles have diverse applications in biomedical analysis and therapy, environmental remediation, and nanoscale and microscale manipulation. However, it is difficult to quantitatively measure the magnetic properties of single nanoparticles with high throughput. This measurement problem limits the ability to perform quality control in manufacturing processes for magnetic nanoparticles, which in turn limits the ability to obtain reproducible and predictable results in commercial applications of magnetic nanoparticles. Through its ongoing inter-OU Nanoparticle Manufacturing Program and recent workshop, [Advancing Nanoparticle Manufacturing \[1\]](#), NIST has clearly identified the need of its stakeholders for new measurement technologies to solve this problem. Because of the widespread use of magnetic nanoparticles, there is a particular need for economical technologies that are commercially available to the many manufacturers and users of magnetic nanoparticles with diverse properties. NIST in general, and the Center for

Nanoscale Science and Technology in particular, is interested in enabling innovative commercial research to close this measurement gap and fulfill its mission to support the U.S. nanotechnology enterprise from discovery to production by providing industry, academia, NIST, and other government agencies with access to nanoscale measurement and fabrication methods and technology.

The general goals of this project are to increase private sector commercialization of an innovative measurement technology, to use small business to meet federal research and development needs, and to stimulate small business innovation in technology. The specific goals of this project are to develop an innovative measurement technology that enables quantitative magnetometry of single nanoparticles with diverse properties with high throughput, and to develop a manufacturing process that enables the mass production of this measurement technology.

Nanoparticles require routine characterization for quality control to obtain reproducible and predictable results in research and development, manufacturing, commerce, and standardization. But there are no commercially available technologies to quantitatively measure functionally relevant magnetic properties of single nanoparticles, such as hysteresis loops and magnetic anisotropy, with industrially relevant throughput. Most existing instruments for magnetometry are intended for measurements of macroscopic sample volumes. Application of these instruments to nanoparticle samples requires measurement of many particles in an ensemble, complicating a quantitative interpretation of the data and obscuring the distribution of particle properties. More specialized instruments for magnetometry can resolve single nanoparticles, but the throughput of such measurements is low, limiting the rapid analysis of a large number of single particles to populate a distribution of properties. Measurement of distributions of magnetic properties is essential to characterize sample heterogeneity for quality control in nanoparticle manufacturing.

Commercial development of an innovative and economical measurement technology will benefit manufacturers and users of magnetic nanoparticles, as well as manufacturers of scientific instruments. The widespread availability of this measurement technology will enable nanoparticle manufacturers to improve quality control of magnetic nanoparticles, allowing users to obtain reproducible and predictable results using the samples and potentially implement the measurements themselves. Growth in this overall market will motivate instrument manufactures to further develop the technology to serve the market better.

Phase I expected results:

Demonstrate quantitative magnetometry of nanoparticles with high throughput, as defined by the following performance metrics: measurements of coercivity with a limit of uncertainty of less than 1 mT; measurements of isotropic or anisotropic nanoparticles with at least one critical dimension of less than 100 nm; measurement of more than 100 single ferromagnetic nanoparticles in less than 100 minutes.

Phase II expected results:

Demonstrate broad applicability of the measurement technology to a variety of commercially relevant magnetic nanoparticles with diverse magnetic properties. Demonstrate different forms of magnetometry including vector magnetometry. Increase the precision of the measurement technology by an order of magnitude. Increase the throughput of the measurement technology by an order of magnitude. Develop an economical manufacturing process for the measurement technology that is suitable for production and commercial venture.

NIST staff may be available to work collaboratively to develop the technology.

Reference:

[1] Advancing Nanoparticle Manufacturing, <http://www.nist.gov/cnst/anm.cfm>.

9.02 Biomanufacturing

9.02.01 Measurement Tools to Advance the Development and Manufacturing of Biologic Medicine

Biologic medicines represent the largest sector of the U.S. bioeconomy, with a global market of \$145 billion, growing at greater than 15% annually and employing more than 810,000 workers. In 2013, seven out of ten of the top-selling drugs were biologics, specifically protein therapeutics, and it is projected that by 2020, 50% of all prescription drugs sales will be biologics. A general unmet need in the development and manufacturing of these products is the inability of the current state-of-the-art in measurement technology to characterize these complex protein products with sufficient precision and accuracy to ensure desirable clinical performance.

NIST seeks the development of new or improved measurement tools and methods that can more quickly, accurately, and precisely characterize the structure of biologic drugs.

Advances in such measurement technology will:

- Enable faster and more confident assessments of the potential effects of changes in the manufacturing process, equipment, or raw materials.
- Aid development of biosimilars that will lead to greater competition and improved access to many medications for US patients.
- Increase general knowledge in the field of biopharmaceuticals and allow industry to develop improved and next generation protein therapeutics.

New analytical methods that can more accurately assess finished products, as well as analytical tools that can monitor attributes biologic throughout the manufacturing process are desirable. This opportunity applies to all types of analytical methods including those used for process monitoring, characterization, or lot release. New analytical tools or

methods to be developed should have some advantage over current analytics in terms of higher resolution (greater sensitivity, orthogonality, or specificity), reliability, or the clinical relevance of the product attribute that is measured.

The development of new or improved analytical technologies to assess the product quality attributes below are of interest in this opportunity.

- **Post-translation Modifications**
Many protein therapeutics have post-translational modifications that are critical to their clinical activity. These modifications are typically complex and heterogeneous, and analytical methods for fast qualitative or quantitative assessment of these modifications and how they relate to potency and clinical performance need to be improved. For example, glycosylation of the Fc region of many monoclonal antibody therapeutics is important for their mechanism of action in cancer treatment. Of particular interest in this opportunity are improved methods for quickly analyzing and quantifying glycosylation and other modifications known to affect the efficacy and safety of these types of products. Analytical technologies to improve measurement of other post-translational modifications including deamidated species, glycated species, sialylated species, C-terminal variants (HC -Lys, HC-Pro Amide), N-terminal variants (Gln vs pyro Glu), and oxidized forms would also be of interest.
- **Higher Order Structure**
Protein therapeutics must be folded into a three-dimensional structure to become functional and often a three-dimensional structure can be misfolded. It is possible that a distribution of three dimensional structures can exist for a product where there will be one major three-dimensional structure present with other minor variants differing in three-dimensional structure. We seek the development of new or improved higher order structure measurement tools that can detect and quantify the properly folded three-dimensional structure along with misfolded variants of protein therapeutics.
- **Protein Aggregation and Particulates**
Protein molecules can stick to each other to form aggregates which are thought to be the precursors to formation of larger particulate species. It is believed that these species have the potential to stimulate adverse immune responses in patients that can lead to neutralization of the protein therapeutic. Aggregation and particulate formation are particularly problematic for monoclonal antibody therapeutics that are typically formulated at high concentrations of 100 mg/ml or greater. In order to better understand adverse immune reactions, the ability to measure and quantify different types of aggregates in products needs to be improved. We seek the development of new or improved analytical tools that can directly measure the size and shape of protein aggregates or particulates, or assess their composition.

For assessment of all the product attributes above, new or improved analytical technologies or methods that require minimal sample preparation, or are capable of interrogating high

concentration, formulated protein therapeutics, or protein therapeutics in raw process streams are also of particular interest in this opportunity.

Phase I expected results:

Establish proof of concept of new or improved analytical technology to measure desired product quality attribute (s) of protein therapeutics. Optimize and establish performance characteristics of new or improved analytical technology including sensitivity, resolution, quantitation, measurement speed (including sample preparation steps), accuracy, precision, and reproducibility.

Phase II expected results:

Directly compare results of new or improved analytical technology with results from a current state-of-the-art analytical method (can be conceptually similar or orthogonal analytical method) used for characterization or product release testing of protein therapeutics. Demonstrate a factor of 2X or greater improvement in sensitivity, resolution, accuracy, precision, or speed of the new or improved analytical technology.

NIST will be available to consult or for potential collaboration with the awardee depending on the measurement technology to be developed. NIST will also be willing to provide where appropriate reference materials to better compare performance of the proposed new method or technology with that of the current state-of-the-art.

9.03 Cryptography and Privacy

9.03.01 Personal Data Stores to put Users in Charge of their Own Information

In working toward National Strategy for Trusted Identities in Cyberspace (NSTIC) aligned online transactions, the NSTIC National Program Office (NPO) has identified current inconveniences that arise when individuals request services and benefits from the government. In these transactions, government websites repeatedly ask individuals for the same personal information. In some cases, websites do not actually need specific values for attributes; they just need a claim (e.g., a claim that a user is in a certain age range, instead of using a birthdate). Users lack a convenient way to disclose requested information without repetitious form filling, transform verified attributes into claims, or track where information has been disclosed, leaving them susceptible to over-collection and over-sharing of personal information. Potentially old and incorrect data also reduces the quality of services, and can be costly for government agencies. Finally, agencies incur security costs and liabilities maintaining personal information in order to communicate with customers. This is not only an issue with government transactions – it's also a part of our everyday interactions with private companies [1-2].

One solution is commonly known as a Personal Data Store (PDS). While commercial pilot programs have demonstrated its utility, it has yet to reach broad adoption in the

government space. A PDS will provide users the ability to grant relying parties – sites that utilize identities or attributes provided by a third party service – secure, ongoing access to their personal information, attributes, and preferences. Hosted PDSs are segmented away from the rest of an information system, insulating private information and attribute details. Individuals will retain full control of their personal information; they'll decide which attributes to release or permit access to and to whom.

The PDS should meet several critical requirements:

- Interoperate with a countless number of agencies or private companies engaging customers in online transactions by using open standards to transmit and store personal information and attributes;
- Revoke access to information provided to third or relying parties, and provide individuals with a clear and usable method for managing access to their stored data;
- Allow users to download their data in an open, portable format that can be migrated to other PDSs, maintaining the focus on user choice and convenience;
- Store, or link to, credential and attribute verifications from credential and attribute service providers, allowing individuals to share both self-asserted and signed or verified data about themselves;
- Provide the option for users to disclose verified attributes without revealing the user's relationship with the relying party to the verifying credential or attribute service provider or revealing the user's relationship with the verifying credential or attribute service provider to the relying party; and
- Transform verified attributes into provable claims.

Through the PDS, the user will manage their self-asserted data as well as provide access to any user-approved external authoritative sources. The PDS will be beneficial when citizens engage with government agencies online – especially through Connect.Gov. With Connect.Gov, individuals will be able to use their credentials from approved external websites to log in at federal websites. A personal data store would put citizens in control of their personal information in these transactions, cultivating trust in Connect.Gov. As the private sector becomes increasingly competitive regarding privacy, and more devices request information a part of the growing Internet of Things, tools like PDSs provide more privacy benefits by helping individuals manage their information disclosures, as well as increasing trust in online transactions across the Internet.

PDSs will enable trust, accuracy and convenience for individuals providing the same information to multiple agencies and companies without needing to fill out cumbersome, error-prone forms. Additionally, it will improve service delivery of the U.S. government by allowing its authoritative data to be made available, if an individual chooses, through a PDS. This is a unique opportunity for a provably secure, technical solution to keep personal information under user control at a time when well-intentioned government actions toward data protection are so often met with suspicion. PDSs will provide a more explicit approach

to consent, giving individuals greater control over what information is released, under what conditions, and to whom.

Phase I expected results:

Develop the architecture and a functioning prototype of the PDS, including user interfaces. These should be testable and deployable, as well as have integration abilities based on open standards.

Phase II expected results:

Develop an open-source PDS architecture based on open standards (where applicable). Demonstrate successful integration into the Connect.Gov architecture and successfully test and pilot this integration with at least two applications at different federal agencies. NIST will provide consultation and input through regular discussions to solve problems as they occur. NIST will also work with General Services Administration (GSA) and other agencies to provide the test applications through Connect.Gov to which the integration will occur.

References:

[1] National Strategy for Trusted Identities in Cyberspace (http://www.whitehouse.gov/sites/default/files/rss_viewer/NSTICstrategy_041511.pdf).

[2] Privacy Enhancing Technologies Workshop (<http://www.nist.gov/itl/csd/ct/pec-workshop.cfm>).

9.04 Cyber Physical Systems

9.04.01 A Category-Theoretic Tool for Modeling Cyber-Physical Systems

The ability to compose existing interacting systems into a single higher-level system is essential to several emerging transformational technology platforms, such as cloud services, the Internet of things (IoT), and cyber-physical systems (CPS). On a small scale, this has been achieved by data exchange formats, programming language interfaces, and algebraic specification frameworks. However, a formal account of modularity for large-scale systems has been out of reach. Category theory, as a theory of structure and compositionality, stands out as a possible mathematical formalism for specifying, analyzing, and composing large-scale modular structures. This SBIR subtopic is calling for a software tool to test the categorical formalism on a testbed of interacting systems composition problems. The software tool should be able to create categorical models of systems composition and show that these models apply to concrete problems, such as those occurring for cyber-physical systems. The work proposed should lead to new generation of tools that will enhance the ability to build, test, and validate this new generation of cyber-physical systems [1]. The goal of the project is to create suite of tools based on category theory to transcend current ad-hoc practices in the creation of large-scale cyber-physical systems. The project

will demonstrate the ability to define, build, test and validate the design of cyber-physical systems. Given their possible ubiquity in the future, it is important to have good formal methods that form the basis of design for cyber-physical systems and the internet of things.

Phase I expected results:

Demonstrate the feasibility of creating tools based on category theoretic foundations through exemplars of such a system. Evaluate the market needs and requirements of such tools.

Phase II expected results:

Develop and demonstrate the use of the tools proposed in Phase I, involving potential customers. Develop business plans and a detailed path to commercialization.

NIST may work both in consultative and collaborative capacity in assisting the awardee.

Reference:

[1] Lee, E.A. "Cyber Physical Systems: Design Challenges", International Symposium on Object/Component/Service-Oriented Real-Time Distributed Computing (ISORC), May, 2008; Invited Paper.

9.04.02 Process Reference Data for Sustainability

Current approaches to understanding the environmental impacts of manufactured products are based on a methodology known as life cycle assessment (LCA.) LCA uses generalized estimates for the impact of the different processes involved in the manufacturing of these products. The actual impacts of manufacturing processes can vary dramatically and are influenced by a wide range of factors, including the manufacturing operating environments and process settings and the cost and availability of labor, energy and materials [1-3].

The LCA tools available today focus on material production and use sustainability approximations that fail to account for specific manufacturing process performance, thus resulting in uncertain comparisons. With newer equipment, or by outfitting older equipment with sensors, we are able to accurately measure many of the factors contributing to the overall sustainability impact, such as energy, water, and material use; however, each process assessment is time consuming and the results are not widely shared.

An easily accessible source of manufacturing process reference data would allow more accurate assessments of the overall sustainability impact. A collection of reference data of manufacturing processes which use formal representation methods capable of integrating into software solutions such as analysis packages will be useful for industry decision making, integration with LCA solution providers, and educational purposes in general. For example, this reference data could be incorporated by solution providers to analyze manufacturing plans to reduce the impact of the manufacturing processes in terms of the environment, as

well as operational costs. The data could further be used to predict production costs, schedule manufacturing resources, and control quality of production.

The repository of reference data should support collaboration for data contributions from a variety of sources, mechanisms for rating data accuracy and validity, mechanisms for people to find relevant data sources, and mechanisms to support automated interfaces to the repository. Furthermore, a business model for providing a viable service is needed. Reference data collection is a time consuming and the resulting data may contain sensitive information. The project should outline a business model that will support a variety of different stakeholder needs including academic research, industry specific interests, and integration with an enterprise's proprietary reference data.

The goal of this project is to make manufacturing process sustainability reference data available to enable accurate estimates of the impact of manufacturing processes. Process reference data can facilitate process trade-off analysis that will result in an overall reduction of the impact of manufacturing activities and that will reduce costs to manufacturers.

Phase I expected results:

Demonstrate a framework for collecting unit manufacturing process data in a standard and reusable way from a range of contributors, making use of emerging standards from ASTM E60.13, Committee on Sustainable Manufacturing, for process characterization and the development of standard templates for information collection, storage, and retrieval. The reference data set should provide at a minimum the information needed for composing the unit manufacturing processes for purposes of sustainability-related decision support. Create and provide such a database to address existing gaps on manufacturing process- specific information for life cycle analysis. The framework will include methods to support collaborative contribution, open discussion, and rating of contributed process data.

Phase II expected results:

Develop a repository of reference data sets for manufacturing processes represented in Phase I using a standardized format suitable for access by both end users and software applications. The repository should accept and solicit contributions of data and provide mechanisms for the data to be reviewed and discussed. Features for determining the validity and accuracy of the datasets should be considered. The number of manufacturing processes in use is so large that collaborative development of the data sets will be necessary in order for the system to have broad coverage increasing its usefulness. Provide a collection of unit manufacturing process data to a wide range of manufacturing customers either directly or through providers of manufacturing analysis solutions. Provide a variety of innovative mechanisms to make the data available.

NIST will be available to work collaboratively with the awardee providing consultation and input on the standards activities and directions and connecting a network of data providers.

References:

[1] Sustainability-related standards are currently being developed by standards development agencies such as ASTM International.

<http://www.astm.org/WorkItems/WK35705.htm>.

[2] Unit process life cycle inventory (UPLCI), as part of the CO2PE! Initiative is an international effort to document, analyze, and improve the environmental footprint for a wide range of manufacturing processes. <http://www.co2pe.org/>.

[3] Mani, M., Madan, J., Lee, J.H., Lyons, K.W. and Gupta, S.K. "Sustainability characterization for manufacturing processes", International Journal of Production Research 52 (20), 5895-5912; <http://www.tandfonline.com/doi/abs/10.1080/00207543.2014.886788>.

9.04.03 Novel Methods for Determining Commercial Building Envelope Airtightness

Today, there are an estimated 8 billion square meters of commercial building space in the U. S., which consume 19 % of the energy used in the U. S. [1]. A report by the U. S. Department of Energy estimates that reducing air leakage through the exterior envelope of commercial buildings could result in energy savings of over 800 TBtu U. S.-wide by 2030 (5 % of the energy consumed by commercial buildings in 2014) [2]. Leaky building exteriors also lead to moisture issues inside wall cavities and building interiors, which can affect the integrity of the building envelope and the health of the occupants [3, 4]. However, barriers to making improvements in building envelope airtightness include not knowing a building's current airtightness and thus not knowing how much energy (and thus money) one could save by investing in airtightness improvements. The current primary technique for determining building envelope airtightness is the building pressurization test, which is standardized in the American Society of Testing and Materials (ASTM) Standard E779-10 [5]. However, many building owners, tenants, and other stakeholders choose not to conduct this test because of the cost, time, and disruption to day-to-day building operations. It has also been shown that building envelope airtightness does not correlate to building age or construction characteristics [6].

Another method to determine building envelope airtightness is to use building energy models calibrated by utility data. Changes to equipment operation and efficiency, and to occupant usage are made in the model to reflect differences between design assumptions and operating conditions (e.g. [7]). When significant differences still exist after these changes are made, they are attributed to unknowns in the input parameters, such as building envelope airtightness. This value may be then adjusted using engineering expertise. However, it is difficult to know whether the airtightness value identified during the calibration process is the actual value or merely one that matches the modeling results and utility data.

Thus, a novel method is needed to determine building envelope airtightness that would be attractive to building owners and tenants. Such a method should be lower in cost, time, and

effort and be less disruptive than the current best available technology, i.e., building pressurization testing. It should also provide a building envelope airtightness value with more confidence than calibrating energy models to coarse utility data. The new method should be accessible to the entire building industry. A commercial product that can deliver envelope airtightness values to clients would be crucial when faced with choosing whether or not to make capital investments to increase of airtightness. It would also allow building energy modelers to increase the confidence in their model results since infiltration is the one of the largest sources of the uncertainty [8].

The adoption of such a method has the potential to improve the airtightness and energy usage of innumerable commercial buildings. In addition, improved airtightness can prolong the life of buildings reducing or eliminating moisture migration into the building. The development of a method to easily determine building envelope airtightness would serve NIST in satisfying its goal by advancing the measurement science in this field. It would also serve the U. S. in reaching its goals to reduce reliance on oil and improve energy security [9].

The method developed to determine building envelope airtightness should be lower in cost, time, and effort and be less disruptive to normal operations compared to currently available technology. It should also provide a building envelope airtightness value with more confidence than calibrating to coarse utility data. It should be a method that can be used in a variety of building types including, but not limited to, stand-alone, those with shared walls, single story, and skyscrapers. The airtightness values determined by such a method should include bounds of uncertainty and be validated with pressurization test results. The method should be demonstrated in actual commercial buildings, with both multizone airflow and energy models of the buildings developed to support future research.

Phase I expected results:

Develop a literature review or market research demonstrating their knowledge of the state of the art in sensors and approaches to determining building envelope airtightness that could be commercialized. Present the details of the proposed feasibility study (or studies) that have high potential to address the need for novel methods to determine building envelope airtightness in commercial buildings. Report the results of their study (or studies), including sensitivity and uncertainty analyses in the Phase I final report.

Phase II expected results:

Provide a schedule to the NIST technical expert on how the method will be developed from Phase I to a final product. Select 3 or more commercial buildings for field testing (to be approved by the NIST technical expert) and obtain written consent to perform building envelope airtightness testing in order to validate the method developed. Identify plans to bring the method to the commercial marketplace and demonstrate that it is lower in cost, time and effort, and less disruptive to normal operations, compared to currently available technology. Provide a building envelope airtightness value with more confidence than calibrating to coarse utility data.

The NIST technical expert will be available for consultations and discussions to answer questions and clarify any other technical aspects of this effort.

References:

[1] DOE. Building Energy Data Book. 2011 [cited 2014; Available from: <http://buildingsdatabook.eren.doe.gov/>

[2] DOE, Windows and Building Envelope Research and Development: Roadmap for Emerging Technologies. 2014, U. S. Department of Energy: Washington, D. C.

[3] Bomberg, M., Kisilewicz, T. and Nowak, K. “Is there an optimum range of airtightness for a building?”, *Journal of Building Physics*, 2015.

[4] IOM, “Damp Indoor Spaces and Health”, *I.o. Medicine*, Editor. 2004, The National Academies Press: Washington, D.C.

[5] ASTM, ASTM E779-10 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization. 2010, American Society of Testing and Materials: Philadelphia.

[6] Emmerich, S.J. and Persily, A.K. “Analysis of U. S. Commercial Building Envelope Air Leakage Database to Support Sustainable Building Design”, *International Journal of Ventilation*, 2014. 12(4): p. 331-343.

[7] Raftery, P., Keane, M. and Costa, A. “Calibrating whole building energy models: Detailed case study using hourly measured data”, *Energy and Buildings*, 2011. 43(12): p. 3666-3679.

[8] Hopfe, C.J. and Hensen, J.L.M. “Uncertainty analysis in building performance simulation for design support”, *Energy and Buildings*, 2011. 43(10): p. 2798-2805.

[9] Obama, B., “The President's Climate Action Plan”, 2013: Washington, D. C.

9.04.04 Single-Chip eLoran Receiver

The Global Positioning System (GPS) is used for a myriad of innovative—and now, essential—applications that were not envisioned when the system was first designed [1]. The Department of Homeland Security reports that of their 18 defined areas of U.S. critical infrastructure (e.g., communications, transportation, and energy), 16 of them rely on GPS for precision timing and synchronization in their system operations [2]. However, the GPS signal is exceedingly weak, and it is vulnerable to interference, both accidental and deliberate.

Programs have been proposed to provide resilience to the many modern cyber physical systems that rely on GPS for timing data. One that is often suggested is “eLoran,” which could augment GPS by providing a complementary data transmission channel for timing and more [3–8].

One of the developments that allowed GPS service to become so widely used was the development of application-specific integrated circuits (ASICs) that allowed engineers to incorporate GPS receivers into their products at very low cost (a few dollars or less). No such single-chip receivers currently exist for eLoran. Development and demonstration of ASICs for eLoran, or ASICs that integrate eLoran receiver functionality with that of other systems, would accelerate adoption and utilization of eLoran if and when it is deployed. While NIST has no operational responsibility for either GPS or eLoran, NIST seeks development of eLoran ASICs in order to help facilitate the broad dissemination of precise, accurate time standards and to provide robustness and resilience for critical cyber physical systems.

The goals of this project are to develop and demonstrate reference designs for single-chip eLoran receivers (ASICs). These designs could be for stand-alone eLoran receivers or—even better—integrated into ASICs that receive multiple time-dissemination signals (e.g., GPS, NIST’s WWVB). Designs must take care to capture all the timing precision available in these signals, and the designs must be amenable for eventual mass production at very low cost (commensurate in cost to today’s ASICs that provide precision time but which lack eLoran compatibility).

As of this writing, the only U.S. eLoran signal is broadcast from Wildwood, NJ, and on an intermittent, experimental basis. The signal has a coverage radius of a few hundred miles. Proposals under this subtopic (Phase I now, and perhaps a Phase II later) should make clear the extent to which access to this signal might be required, and what if any arrangements might have been made for access to this signal when needed. Neither the U.S. Government nor its CRADA partners [9] make any representation or commitment through this SBIR solicitation that this signal would be available or guaranteed. Open-air eLoran signals may also be available in the UK and other nations [10].

Phase I expected results:

Develop a feasibility study consisting, at a minimum, of a system design and supporting analysis for timing accuracy and volume manufacturing costs. The design should be based on published eLoran specifications (e.g., [3–7]) and the analysis should greatly benefit from experimental validation of elements in the design.

Phase II expected results:

Production of prototype integrated circuits. The prototype should be produced to the specifications to meet the needs for functionality testing and support the broad and rapid commercialization of eLoran technology.

NIST will not provide assistance on this project.

References:

[1] See <http://www.dhs.gov/science-and-technology/cyber-physical-systems>.

[2] See <http://www.gps.gov/multimedia/presentations/2012/10/USTTI/graham.pdf>.

[3] The eLoran definition document may be found at:

<http://www.loran.org/news/eLoran%20Definition%20Document%200%201%20Released.pdf>.

[4] The Loran C signal specification may be found at:

<http://www.navcen.uscg.gov/?pageName=loranSignalSpec>.

[5] The eLoran 9th pulse modulation technique is described in http://www-personal.umich.edu/~tmikulsk/loran/ref/eloran_idc.pdf and

<http://www.dtic.mil/get-tr-doc/pdf?AD=ADA575171>.

[6] See <http://rntfnd.org/wp-content/uploads/Delivering-a-National-Timescale-Using-eLoran-Ver1-0.pdf> and the references therein.

[7] See http://www-personal.umich.edu/~tmikulsk/loran/index_3.html and the references therein.

[8] Additional background information on eLoran and updates on its current status may be obtained by searching on that term with an Internet search engine.

[9] See <http://www.exelisinc.com/news/pressreleases/Pages/Exelis,-UrsaNav,-DHS-and-the-U.S.-Coast-Guard-enter-agreement-to-trial-ground-based-position,-navigation-and-timing-signal.aspx>.

[10] See <http://www.gla-rnav.org/radionavigation/eloran/index.html>.

9.04.05 Smart Visualization of Smart Manufacturing

Today's manufacturing systems are able to collect vast amounts of data; however, much of that data is never used unless and until there is a known problem in the process. Sometimes the problem will not even be detected until the product is being used in the field, implying that the manufacturing problem may have persisted for several generations of the product. Advances in data visualization, which is a fundamental means of observing data and discovering problems, have come a long way for generalized applications. Data visualization still requires considerable effort to easily integrate with the systems generating data [1].

Current approaches (drag-and-drop dashboards, tableaus, etc.) to visualizing smart and

sustainable manufacturing enterprises are quite limited and suffer from many drawbacks. Substantial manual effort from specialized practitioners is required to use them. In some cases, significant skilled programming is necessary. In other cases, significant visualization expertise is necessary. Understanding large amounts of big data, often stored as combinations of relational and non-relational data in a variety of quasi-federated databases or being streamed directly from machines, are not well understood by anyone in an enterprise add to further difficulty. Combining all of these skills in a single person is unlikely and are likely to remain out of reach, particularly for small manufacturers. (Large manufacturers have similar problems although for different reasons – while visualization teams exist, inordinately larger data sets make visualization harder in its own way.) Even the best results are currently inflexible, unable to adapt to in-process schema changes or schema-less databases. This leads to inflexible software that either suffers from “bit rot” as schemas and databases change out from under the visualization software or from the inability to incorporate new data to improve visualizations.

Manufacturing systems pose other unique characteristics for data. For instance, correlations between time and spatial coordinates are one fundamental concept for assessing manufacturing performance. Performance is often plagued by the interaction of variables along multiple dimensions, rather than a two-factor correlation. Other unique characteristics also exist.

This project will investigate fundamental concepts that are of relevance to manufacturing data, develop procedures for applying visualization techniques to those concepts, and provide a natural language-based user interface to allow manufactures to quickly assemble their own visualizations based on their datasets.

The project goal is to make available manufacturing visualization software that is flexible, powerful, and easy-to-use. A natural language-based front-end is a necessary component and a superior interface to traditional drag-and-drop techniques. The system should be able to give advice to the user, for example, proffering certain visualization techniques for data that is recognizably appropriate or dissuading the use of visualization techniques that are inappropriate for given data. The software should include an expandable library of plugin visualization components allowing for new visualization technologies as they become available. A visualization browser must offer and suggest appropriate choices to deal with challenging data such as high-dimension data. A backend data crawler should be able to adapt to new data as it becomes available within the enterprise, with and even without explicit schemas. Application programming interfaces (API) should be provided so that visualizations may be augmented with scripts using arbitrary programming languages and the results integrated into other software without restrictive licenses.

Phase I expected results:

Demonstrate the feasibility of software for visualizations using limited natural language - based on a library of visualizations and manufacturing “big data” (large and varied databases).

Phase II expected results:

Demonstrate richer natural language interfaces, techniques to recommend visualizations based on data, and API libraries for both new visualizations and integration into other software. Demonstrate the interaction of non-visualization specialists with the system. Produce visualizations that are better than commercially-available spreadsheet packages such as Microsoft Excel, and at least as good as those from such as R, Wolfram, D3JS, but with the capability to produce visualizations much more quickly and without the development time or skills required by current commercially-available visualization software such as those mentioned here.

NIST is available to work collaboratively with the awardee providing consultation and input on the activities and directions and providing data and scenarios.

Reference:

[1] Visualization-related collections described in “visualization zoos” such as <https://queue.acm.org/detail.cfm?id=1805128>, <http://www.idea.org/blog/2012/10/25/great-tools-for-data-visualization/>, and <http://d3js.org>.

9.05 Lab to Market

9.05.01 NIST Technology Transfer

NIST owns inventions that require additional research and innovation to advance the technologies to a commercial product or service. The goal of this SBIR subtopic is for small businesses to advance NIST-owned inventions to the marketplace. The Technology Partnerships Office at NIST will provide the awardee with a royalty-free research license for the duration of the SBIR award. When the technology is ready for commercialization, a commercialization license will be negotiated with the awardee.

Applications may be submitted for the development of any NIST-owned invention that is covered by a pending U.S. patent application or by an issued patent. Available NIST-owned inventions can be found on the NISTTech website at <http://tsapps.nist.gov/techtransfer/> and are identified as “available for licensing” under the heading “Status of Availability.” Some available technologies are described as only being available non-exclusively, meaning that other commercialization licenses may currently exist. More information about licensing NIST’s inventions is available at <http://www.nist.gov/tpo/Licensing.cfm>.

The technical portion of an application should include a technical description of the research that will be undertaken. Included in this technical portion of the application, the applicant should provide a brief description of a development plan to manufacture the

commercial product or to develop a commercial service using the NIST-owned invention. The absence of this development plan will result in the application being less competitive.

Phase I expected results:

Develop a feasibility study that examines expectations of the research to produce a commercial product.

Phase II expected results:

Provide further R&D that leads to demonstrated practical application and advancement toward a commercial product.

NIST staff may be available for consultation and collaboration.

9.06 Materials Genome

9.06.01 Infrastructure Requirements and Architecture to Enable Scalable Scientific Data and Metadata Acquisition and Curation in Support of the Materials Genome Initiative

As a part of the Materials Genome Initiative, NIST is charged with developing a materials innovation infrastructure. Key aspects of this infrastructure include the real-time acquisition and curation of experimental and simulation data and associated metadata and control of scientific equipment over a network. To accomplish this, we need research and development on the core requirements and on an overall strategy and software architecture that would enable control of diverse and geographically distributed experimental equipment (e.g. *scanning electron microscope* (SEM), Transmission electron microscope (TEM), x-ray diffractometers, dilatometry), computational resources (e.g. workstations, clusters, demonstration code), and the automatic capture and curation of their acquired scientific data and associated metadata across a network using backend systems such as the NIST developed Materials Data Curation System and the National Data Service's Material Data Facility [1-3].

The goal of the project is to discover and document core requirements and develop an overall strategy and software architecture that when implemented will allow for the control of geographically distributed NIST research equipment and computational resources and their integration with scientific informatics backends including the NIST Materials Data Curator and the National Data Service's Material Data Facility. Both the Materials Data Curator and the Materials Data Facility have REST APIs to facilitate automated data curation. The project will provide documented requirements and develop a specific strategy and software architecture for controlling NIST scientific instruments and computational resources and interfacing them scientific informatics backends in a format amenable to implementation by software engineers.

Phase I expected results:

Discover, validate, and document requirements for a system to enable scientific equipment

control and scalable scientific data and metadata acquisition and curation as described in the project goals. Using previously documented requirements, develop and document an overall strategy and then develop and document a software architecture that when implemented will meet the project goals. NIST believes that a successful architecture would have several key properties: 1) It would be structured in independent layers, the top-most layer would present a high-level user interface to allow unified user access and control, while the lowest layer would provide connectivity to the scientific equipment or computational output, 2) the architecture relies on two public interfaces one for the highest level and the other at the lowest level that would allow the components to interact as a single application, 3) the architecture includes the notion of a default scripting language and provisions for integrated development environments to facilitate customization and extension of a system implementing the architecture in a standardized fashion, 4) the architecture is highly modular and includes the concepts of plugins and a generalized, abstract command set that facilitates interaction with the scientific equipment, 5) the public interfaces and abstract command set are conceived as being language neutral and allow users to control and extend a system implementing the architecture from a large variety of commonly used programming languages including Python, Java, and C++, 6) the architecture will provide for the capture of scientific provenance and system configuration to facilitate in reproducibility, 7) the architecture will support the concept of scientific workflows.

Phase II expected results:

Develop an extensible infrastructure for the development of APIs to facilitate data curation of materials data from NIST dilatometers, x-ray diffractometers, scanning electron microscopes (EDS- composition scan, EBSD pattern), transmission electron microscopes, and tensile testing machines.

NIST staff familiar with the various instruments (SEM, TEM, optical microscopes, dilatometer, x-ray diffractometer) and simulations will be available to work with awardees to discover the requirements and develop the metadata schemas needed to collect the data. NIST staff responsible for the development of the Materials Data Curation System can be made available to help the awardees understand the architecture and capabilities of the MDCS.

References:

[1] Documentation for Materials Data Curator System
(<https://github.com/usnistgov/MDCS>).

[2] Campbell, C.E., Kattner, U.R. and Liu, Z-K. "File and Data Repositories for the Next Generation CALPHAD", *Scripta Mater.* (2014) **70**, 7-11.

[3] Campbell, C.E., Kattner, U.R. and Liu Z-K. "The development of phase-based property data using the CALPHAD method and infrastructure needs", *IMMI* (2014) **3**

9.07 Quantum-based Sensors and Measurements

9.07.01 Highly Efficient Optical Frequency Converters for Quantum Interfaces

Hybrid quantum networks are a key step towards realizing distributed quantum computing and quantum communications, two areas that promise to fundamentally change the way information is processed, delivered and secured. Hybrid quantum networks consist of quantum components that operate at different optical wavelengths. This is necessary since different functions of the network are best performed by different technologies (e. g. trapped ions, Rydberg atoms, nitrogen-vacancy color centers, etc.) that operate at incompatible wavelengths. Quantum interfaces are needed to make the different nodes compatible. Ideally, these interfaces are optical frequency converters that convert photons of one wavelength to another with 100% conversion efficiency and no additional noise. In practice, up to 86% internal conversion efficiency has been demonstrated [1] using periodically poled lithium niobate (PPLN) waveguides, and when coupling and collection losses are included, external conversion efficiencies between 51% [2] and 65% [1] have been shown. Furthermore, these devices have been developed by academic institutions and to our knowledge, no commercial vendors exist that can achieve this level of performance. An unmet need exists for a commercial source of high-efficiency, high-performance optical frequency converters. Efficient, low-loss converters are needed for both up- and down-conversion. Devices must be able to efficiently convert between far-separated wavelengths, which requires on-chip mode conditioning and directional coupling [3]. Attention to packaging and fiber coupling is needed to make the devices robust and easy to use. NIST is interested in these devices to further efforts in realizing a hybrid quantum network. We are seeking proposals from US industry to develop reliable, high-efficiency devices and demonstrate a path towards commercialization.

The goal of this project is to develop commercial facilities and capabilities to manufacture, characterize and test high-performance optical frequency converters. High performance includes high conversion efficiency, low noise, robust packaging, good long-term stability and performance free of photorefractive damage. High external conversion efficiency requires excellent waveguide quality, low propagation losses and high coupling efficiency. On-chip filters and couplers are likely needed to achieve high launching and coupling efficiencies.

Phase I expected results:

Demonstration of expertise and capability in fabricating high-efficiency waveguides. Design and verification via modeling for high conversion efficiency, high efficiency input and output coupling (likely utilizing on-chip filters) for (a) upconversion between 1892 nm + 1550 nm → 852 nm and (b) down-conversion between 852 nm + 1892 nm → 1550 nm.

Phase II expected results:

Demonstrate packaged, fiber-coupled optical frequency converters for upconversion and downconversion. Fiber-coupling should enable high launching efficiencies of both pump and signal beams, which will likely requires two separate input fibers and on-chip beam combining. Develop waveguides with at least 80% internal conversion efficiency and 50% external conversion efficiency using a continuous-wave (CW) pump. The devices should achieve maximum conversion with input CW pump power below 1W. Demonstrate capability to characterize (a) internal and external conversion efficiencies, (b) waveguide propagation losses, (c) input coupling efficiency, accounting for facet, fiber-pigtailing and mode-matching losses, and (d) output coupling efficiency. Demonstrate fabricated waveguides for both processes mentioned in phase I and show the designs can be adapted and executed at other wavelengths, for instance processes having pump longer than 2100 nm.

It is expected that NIST researchers will be available for consultation and input.

References:

[1] Pelc, J.S., Ma, L., Phillips, C.R., Zhang, Q., Langrock, C., Slattery, O., Tang, X. and Fejer, M.M. "Long-wavelength-pumped upconversion single-photon detector at 1550 nm: performance and noise analysis", *Opt. Express* **19**, 21445-21456 (2011).

[2] Kuo, P.S., Pelc, J.S., Slattery, O., Kim, Y.S., Fejer, M.M. and Tang, X. "Reducing noise in single-photon-level frequency conversion", *Opt. Lett.* **38**, 1310-1312 (2013).

[3] Pelc, J.S., Yu, L., De Greve, K., McMahon, P.L., Natarajan, C.M., Esfandyarpour, V., Maier, S., Schneider, C., Kamp, M., Höfling, S., Hadfield, R.H., Forchel, A., Yamamoto, Y. and Fejer, M.M. "Downconversion quantum interface for a single quantum dot spin and 1550-nm single-photon channel", *Opt. Express* **20**, 27510-27519 (2012).

Appendix A. COVER SHEET

(A fillable version of the Cover Sheet is available at <http://www.nist.gov/sbir>)

Application to National Institute of Standards and Technology (NIST) Small Business Innovation Research (SBIR) Program 2016-NIST-SBIR-01 Cover Sheet			
Name of Submitting Firm		Click here to enter text.	
Subtopic Number	Click here to enter text.	Project Title	Click here to enter text.
Principal Investigator (PI) Name	Click here to enter text.		PI Title Click here to enter text.
PI Phone #	Click here to enter text.	PI E-mail	Click here to enter text.
NIST may verify the following responses with information provided elsewhere in your application or by independent sources.			
THE APPLICANT CERTIFIES THAT:			
1. It is a small business concern (SBC) and meets the definition as stated in this Federal Funding Opportunity (FFO).		<input type="checkbox"/> Yes <input type="checkbox"/> No	
2. The primary employment of the PI will be with the SBC at the time of award and during the conduct of research.		<input type="checkbox"/> Yes <input type="checkbox"/> No	
3. A minimum of either two-thirds for Phase I or one-half for Phase II of the research will be performed by the SBC as determined by data provided in the Budget Narrative. See FFO Section 1.03 for details on funding determination.		<input type="checkbox"/> Yes <input type="checkbox"/> No	
4. The applicant and/or PI <input type="checkbox"/> has / <input type="checkbox"/> has not submitted applications for essentially equivalent work under other Federal program FFOs and <input type="checkbox"/> has / <input type="checkbox"/> has not received other Federal awards for essentially equivalent work. If "has", what agency? Click here to enter text.			
See FFO Section 3.02.02(13) (Phase I) for additional details that must be provided.			
THE FOLLOWING ITEMS ARE FOR STATISTICAL PURPOSES:			
5. The applicant qualifies as a socially and economically disadvantaged SBC and meets the definition as stated in this FFO.		<input type="checkbox"/> Yes <input type="checkbox"/> No	
6. The applicant qualifies as a woman-owned SBC and meets the definition as stated in this FFO.		<input type="checkbox"/> Yes <input type="checkbox"/> No	
7. The applicant qualifies as a HUBZone-owned SBC and meets the SBA's definition (see http://www.sba.gov/hubzone).		<input type="checkbox"/> Yes <input type="checkbox"/> No	
8. The applicant qualifies as a veteran-owned SBC.		<input type="checkbox"/> Yes <input type="checkbox"/> No	
The applicant qualifies as a service-disabled veteran-owned SBC.		<input type="checkbox"/> Yes <input type="checkbox"/> No	
9. Year SBC founded:		Click here to enter text.	
10. Number of Employees:		Click here to enter text.	
STATEMENTS:			

<p>11. The applicant will permit the Government to disclose contact information if this application does not result in an award, to appropriate local and State-level economic development organizations that may be interested in contacting you for further information.</p>	<p><input type="checkbox"/> Yes <input type="checkbox"/> No</p>
<p>12. The applicant authorizes contact information and project title to be provided to the NIST Manufacturing Extension Partnership (MEP) after awards have been announced. If 'Yes' your contact information will be provided to NIST MEP. If so, you will be contacted by your local MEP to explore business-related support services that could benefit the potential of the project you proposed.</p>	<p><input type="checkbox"/> Yes <input type="checkbox"/> No</p>
<p>TECHNICAL ABSTRACT (limit to 200 words):</p>	
<p>Click here to enter text.</p>	
<p>POTENTIAL COMMERCIAL APPLICATION OF THE RESEARCH: (limit to 100 words)</p>	
<p>Click here to enter text.</p>	
<p>OTHER INFORMATION:</p>	
<p>Information contained in unsuccessful applications will remain the property of the applicant. The government may, however, retain copies of all applications. Public release of information in any application submitted will be subject to existing statutory and regulatory requirements.</p> <p>Applicants are discouraged from submitting proprietary information unless the information is deemed essential for proper evaluation of the application. If proprietary information provided by an applicant in an application constitutes trade secret, proprietary commercial or financial information, confidential personal information, or data affecting national security, it will be treated in confidence to the extent permitted by law. This information must be clearly marked by the applicant with the term 'confidential proprietary information' and the following legend must appear in this section of the application.</p> <p>PROPRIETARY NOTICE</p> <p>"These data shall not be disclosed outside the Government and shall not be duplicated, used, or disclosed in whole or in part for any purpose other than evaluation of this proposal. If a funding agreement is awarded to this applicant as a result of or in connection with the submission of these data, the Government shall have the right to duplicate, use, or disclose the data to the extent provided in the funding agreement and pursuant to applicable law. This restriction does not limit the Government's right to use information contained in the data if it is obtained from another source without restriction. The data subject to this restriction are contained on pages _____ of this proposal."</p> <p>The use of any other legend is unacceptable to the Government and may constitute grounds for removing the application from further consideration without assuming any liability for inadvertent disclosure.</p> <p>OMB Control No. 0693-0072</p> <p>Expiration Date: 10/31/2017</p>	

Appendix B. CERTIFICATIONS

SBIR Funding Agreement Certification (at time of award)

All small businesses that are selected for award of an SBIR funding agreement must complete this certification at the time of award and any other time set forth in the funding agreement that is prior to performance of work under this award. This includes checking all of the boxes and having an authorized officer of the awardee sign and date the certification each time it is requested.

Please read carefully the following certification statements. The Federal government relies on the information to determine whether the business is eligible for a Small Business Innovation

Research (SBIR) Program award. A similar certification will be used to ensure continued compliance with specific program requirements during the life of the funding agreement. The definitions for the terms used in this certification are set forth in the Small Business Act, SBA regulations (13 C.F.R. Part 121), the SBIR Policy Directive and also any statutory and regulatory provisions referenced in those authorities.

If the funding agreement officer believes that the business may not meet certain eligibility requirements at the time of award, they are required to file a size protest with the U.S. Small Business Administration (SBA), who will determine eligibility. At that time, SBA will request further clarification and supporting documentation in order to assist in the verification of any of the information provided as part of a protest. If the funding agreement officer believes, after award, that the business is not meeting certain funding agreement requirements, the agency may request further clarification and supporting documentation in order to assist in the verification of any of the information provided.

Even if correct information has been included in other materials submitted to the Federal government, any action taken with respect to this certification does not affect the Government's right to pursue criminal, civil or administrative remedies for incorrect or incomplete information given in the certification. Each person signing this certification may be prosecuted if they have provided false information.

The undersigned has reviewed, verified and certifies that (all questions must be responded to by checking the appropriate box):

(1) The business concern meets the ownership and control requirements set forth in 13 C.F.R. § 121.702.

Yes No

(2) If a corporation, all corporate documents (articles of incorporation and any amendments, articles of conversion, by-laws and amendments, shareholder meeting minutes showing officer elections, organizational meeting minutes, all issued stock certificates, stock ledger, buy-sell agreements, stock transfer agreements, voting agreements, and documents relating to stock

options, including the right to convert non-voting stock or debentures into voting stock) evidence that it meets the ownership and control requirements set forth in 13 C.F.R. § 121.702.

Yes No N/A Explain why N/A:

(3) If a partnership, the partnership agreement evidences that it meets the ownership and control requirements set forth in 13 C.F.R. § 121.702.

Yes No N/A Explain why N/A:

(4) If a limited liability company, the articles of organization and any amendments, and operating agreement and amendments, evidence that it meets the ownership and control requirements set forth in 13 C.F.R. § 121.702.

Yes No N/A Explain why N/A:

(5) The birth certificates, naturalization papers, or passports show that any individuals it relies upon to meet the eligibility requirements are U.S. citizens or permanent resident aliens in the United States.

Yes No N/A Explain why N/A:

(6) It has no more than 500 employees, including the employees of its affiliates.

Yes No

(7) SBA has not issued a size determination currently in effect finding that this business concern exceeds the 500 employee size standard.

Yes No

(8) During the performance of the award, the principal investigator will spend more than one half of his/her time as an employee of the awardee or has requested and received a written deviation from this requirement from the funding agreement officer.

Yes No Deviation approved in writing by funding agreement officer: _____ %

(9) All, essentially equivalent work, or a portion of the work proposed under this project (check the applicable line):

Has not been submitted for funding by another Federal agency.

Has been submitted for funding by another Federal agency but has not been funded under any other Federal grant, contract, subcontract or other transaction.

A portion has been funded by another grant, contract, or subcontract as described in detail in the application and approved in writing by the funding agreement officer.

(10) During the performance of award, it will perform the applicable percentage of work unless a deviation from this requirement is approved in writing by the funding agreement officer (check the applicable line and fill in if needed):

- SBIR Phase I: at least two-thirds (66 2/3%) of the research.
 SBIR Phase II: at least half (50%) of the research.
 Deviation approved in writing by the funding agreement officer: _____ %

(11) During performance of award, the research/research and development will be performed in the United States unless a deviation is approved in writing by the funding agreement officer.

- Yes No Waiver has been granted

(12) During performance of award, the research/research and development will be performed at my facilities with my employees, except as otherwise indicated in the SBIR application and approved in the funding agreement.

- Yes No

(13) It has registered itself on SBA's database as majority-owned by venture capital operating companies, hedge funds or private equity firms.

- Yes No N/A Explain why N/A:
-

(14) It is a Covered Small Business Concern (a small business concern that:

(a) was not majority-owned by multiple venture capital operating companies (VCOCs), hedge funds, or private equity firms on the date on which it submitted an application in response to an SBIR FFO; and (b) on the date of the SBIR award, which is made more than 9 months after the closing date of the FFO, is majority-owned by multiple venture capital operating companies, hedge funds, or private equity firms).

- Yes No

It will notify the Federal agency immediately if all or a portion of the work proposed is subsequently funded by another Federal agency.

I understand that the information submitted may be given to Federal, State and local agencies for determining violations of law and other purposes.

I am an officer of the business concern authorized to represent it and sign this certification on its behalf. By signing this certification, I am representing on my own behalf, and on behalf of the business concern that the information provided in this certification, the application, and all other information submitted in connection with this application, is true and correct as of the date of submission. I acknowledge that any intentional or negligent misrepresentation of the information contained in this certification may result in criminal, civil or administrative sanctions, including but not limited to: (1) fines, restitution and/or imprisonment under 18 U.S.C. § 1001; (2) treble damages and civil penalties under the False Claims Act (31 U.S.C.

§ 3729 *et seq.*); (3) double damages and civil penalties under the Program Fraud Civil Remedies Act (31 U.S.C. § 3801 *et seq.*); (4) civil recovery of award funds, (5) suspension and/or debarment from all Federal procurement and nonprocurement transactions (FAR Subpart 9.4 or 2 C.F.R. Part 180); and (6) other administrative penalties including termination of SBIR/STTR awards.

Signature _____ **Date** ___/___/___

Print Name (First, Middle, Last)

Title

Business Name

SBIR Funding Agreement Certification (Life-Cycle Certification)

All SBIR Phase I and Phase II awardees must complete this certification at all times set forth in the funding agreement (see §8(h) of the SBIR Policy Directive). This includes checking all of the boxes and having an authorized officer of the awardee sign and date the certification each time it is requested.

Please read carefully the following certification statements. The Federal government relies on the information to ensure compliance with specific program requirements during the life of the funding agreement. The definitions for the terms used in this certification are set forth in the Small Business Act, the SBIR Policy Directive, and also any statutory and regulatory provisions referenced in those authorities.

If the funding agreement officer believes that the business is not meeting certain funding agreement requirements, the agency may request further clarification and supporting documentation in order to assist in the verification of any of the information provided.

Even if correct information has been included in other materials submitted to the Federal government, any action taken with respect to this certification does not affect the Government's right to pursue criminal, civil, or administrative remedies for incorrect or incomplete information given in the certification. Each person signing this certification may be prosecuted if they have provided false information.

The undersigned has reviewed, verified and certifies that (all boxes must be checked):

(1) The principal investigator spent more than one half of his/her time as an employee of the awardee or the awardee has requested and received a written deviation from this requirement from the funding officer.

Yes No Deviation approved in writing by funding agreement officer: _____ %

(2) All, essentially equivalent work, or a portion of the work performed under this project (check applicable line):

Has not been submitted for funding by another Federal agency.

Has been submitted for funding by another Federal agency but has not been funded under any other Federal grant, contract, subcontract or other transaction.

A portion has been funded by another grant, contract, or subcontract as described in detail in the application and approved in writing by the funding agreement officer.

(3) Upon completion of the award it will have performed the applicable percentage or work, unless a deviation from this requirement is approved in writing by the funding agreement officer (check the applicable line and fill in if needed):

SBIR Phase I: at least two-thirds (66 2/3%) of the research.

SBIR Phase II: at least half (50%) of the research.

Deviation approved in writing by the funding agreement officer: _____ %

(4) The work is completed and it has performed the applicable percentage of work, unless a deviation from this requirement is approved in writing by the funding agreement officer (check the applicable line and fill in if needed):

- SBIR Phase I: at least two-thirds (66 2/3%) of the research.
- SBIR Phase II: at least half (50%) of the research.
- Deviation approved in writing by the funding agreement officer: _____ %
- N/A because work is not completed.

(5) The research/research and development is performed in the United States unless a deviation is approved in writing by the funding agreement officer.

- Yes
- No
- Waiver has been granted

(6) The research/research and development is performed at my facilities with my employees, except as otherwise indicated in the SBIR application and approved in the funding agreement.

- Yes
- No

It will notify the Federal agency immediately if all or a portion of the work authorized and funded under this award is subsequently funded by another Federal agency.

I understand that the information submitted may be given to Federal, State and local agencies for determining violations of law and other purposes.

I am an officer of the business concern authorized to represent it and sign this certification on its behalf. By signing this certification, I am representing on my own behalf, and on behalf of the business concern, that the information provided in this certification, the application, and all other information submitted in connection with the award, is true and correct as the date of submission. I acknowledge that any intentional or negligent misrepresentation of the information contained in this certification may result in criminal, civil or administrative sanctions, including but not limited to: (1) fines, restitution and/or imprisonment under 18 U.S.C. § 1001; (2) treble damages and civil penalties under the False Claims Act (31 U.S.C. § 3729 *et seq.*); (3) double damages and civil penalties under the Program Fraud Civil Remedies Act (31 U.S.C. § 3801 *et seq.*); (4) civil recovery of award funds, (5) suspension and/or debarment from all Federal procurement and nonprocurement transactions (FAR Subpart 9.4 or 2 C.F.R. Part 180); and (6) other administrative penalties including termination of SBIR/STTR awards.

Signature _____ **Date** ___ / ___ / ___

Print Name (First, Middle, Last)

Title

Business Name
