**FY 2013
Small Business Innovation Research
Program**

**SOLICITATION**

**U.S. DEPARTMENT OF COMMERCE**

**National Institute of Standards and Technology**

Opening Date: December 11, 2012

Closing Date: February 25, 2013

**NIST – 13 – SBIR**

PROGRAM SOLICITATION AVAILABLE IN ELECTRONIC FORM ONLY

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

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**US DEPARTMENT OF COMMERCE NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY**

**SMALL BUSINESS INNOVATION RESEARCH (SBIR) PROGRAM**

**SOLICITATION**

**1.0 PROGRAM DESCRIPTION**

**1.01 Introduction**

The National Institute of Standards and Technology (NIST) invites small businesses to submit Phase I research proposals under this solicitation. Firms with strong research capabilities in any of the areas listed in Section 9 of this solicitation are encouraged to participate. Unsolicited proposals are not accepted under the SBIR program.

The SBIR program was originally established in 1982 by the Small Business Innovation Development Act (P.L. 97-219). It was then expanded by the Small Business R&D Enhancement Act of 1992, extending the program to the year 2000 and then to 2008. The program was reauthorized under Public Law 112-81, Section E and extended through September 30, 2017.

Eleven federal agencies set aside a portion of their extramural research and development budget each year to fund research proposals from small science and technology-based firms. The objectives of the SBIR program are to: stimulate technological innovation in the private sector; strengthen the role of small business in meeting Federal research and development (R&D) needs; foster and encourage participation by socially and economically disadvantaged persons and women-owned small business concerns in technological innovation; and increase private sector commercialization of innovations derived from federal research and development. The NIST SBIR Program identifies and solicits proposals in subtopics 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 NIST SBIR program and our laboratory research program, the SBIR topics are the investment priorities areas identified in the NIST Programmatic Plan available at: <http://www.nist.gov/director/planning/planning.cfm>.

NIST offers two types of Subtopics in Section 9 of this solicitation: standard research “R” and tech transfer “TT” Subtopics.

**1.01.01 NIST SBIR “R” Subtopics**

Subtopics with the “R” designation address the objective of stimulating small business innovation in areas that meet NIST’s programmatic goals. The “R” subtopics are designed to give small, high tech companies opportunities to propose cutting-edge innovations that meet NIST’s technological needs and at the same time have market potential beyond NIST.

**1.01.02 NIST SBIR”TT” Subtopics**

Subtopics with the “TT” designation address the objective of increasing the commercial application of innovations derived from Federal R&D. SBIR-TT subtopics identify a commercially promising NIST derived technology and the technological gaps needed to transition it to the marketplace. While NIST Laboratory scientists conduct breakthrough research that leads to innovations, NIST’s efforts do not extend to product development. The remaining work needed to develop NIST technologies for the marketplace requires innovation from the private sector.

Both “R” and “TT” subtopics are intended to cultivate private sector innovation and foster and encourage participation by minority and disadvantaged persons in technological innovation.

Technologies identified with “TT” subtopics are either dedicated to the public domain or are patent protected. If there is no patent or patent application cited, the technology is freely available for use without the need for any license. If a “TT” subtopic cites a patent or patent application, the use of that background invention during the course of the SBIR project requires a patent license. Any proposal responding to a subtopic requiring a license must include an [application](http://www.nist.gov/tpo/sbir/upload/NonExclusiveRoyaltyFreePatentLicenseSBIR.pdf) with the proposal (not counted toward the proposal page limitation).

SBIR awards resulting from “TT” subtopics will include, as necessary, the grant of a non-exclusive research license to use the NIST-owned patented background inventions specifically identified within the “TT” subtopic being awarded. SBIR offerors are hereby notified that no exclusive or non-exclusive 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 such a license. Awardees with contracts for subtopics that identify specific 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 CFR Part 404.

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

**1.02 Three-Phase Program**

Legislation requires the Department of Commerce 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 Small Business Administration through the SBA Policy Directive.

The funding vehicles for NIST’s SBIR program in both Phase I and Phase II are contracts. This solicitation is for Phase I proposals only. A Phase II proposal can be submitted only by a Phase I awardee. NIST has the unilateral right to select SBIR research topics and awardees in both Phase I and Phase II and award several or no contracts under a given subtopic.

**1.02.01 Phase I - Feasibility Research**

The purpose of Phase I is for NIST to determine the technical feasibility of the research the awardee proposes and the quality of the awardee’s performance. Therefore, the proposal should concentrate on describing research that will significantly contribute to proving the feasibility of the proposed research, a prerequisite to further support in Phase II. NIST Phase I awards are up to $90,000 and up to a 6 month period of performance with an additional one month allowed for completion of the Final Report.

**1.02.02 Phase II - Research and Development**

All firms that are awarded Phase I contracts under this solicitation will be given the opportunity to submit a Phase II proposal following completion of Phase I. Instructions for Phase II proposal preparation and submission requirements will be provided to Phase I awardees toward the end of the Phase I period of performance. Phase II Offerors will be required to provide information for the SBA Tech-Net Database System when advised this system can accept their input.

Phase II is the R&D or prototype development phase. It will require a comprehensive proposal outlining the research. NIST Phase II awards are up to $300,000 and up to a 24 month period of performance. One year after completing the R&D activity, the awardee shall be required to report on their commercialization activities.

**1.02.03 Phase III - Commercialization**

In Phase III, it is intended that non-SBIR capital be used by the small business to pursue commercial applications of Phase II. SBIR funds are not available for Phase III.

**1.03 Manufacturing-related Priority**

[Executive Order (EO) 13329](http://edocket.access.gpo.gov/2004/pdf/04-4436.pdf) “Encouraging Innovation in Manufacturing” requires SBIR agencies, to the extent permitted by law and in a manner consistent with the mission of that department or agency, to give high priority within the SBIR programs to manufacturing-related R&D. “Manufacturing-related” is defined as “relating to manufacturing processes, equipment and systems; or manufacturing workforce skills and protection.” More information on the national manufacturing initiative may be found through links located on the [NIST SBIR website](http://www.nist.gov/sbir).

The NIST SBIR Program solicits manufacturing-related projects through many of the subtopics described in this Solicitation. Further, NIST encourages innovation in manufacturing by giving high priority, where feasible, to projects that can help the manufacturing sector through technological innovation in a manner consistent with NIST’s mission. This prioritization will not interfere with the core project selection criteria described in Section 4.03.

**1.04 Energy Efficiency and Renewable Energy Priority**

The Energy Independence and Security Act of 2007 (P.L. 110-140) directs SBIR Programs to give high priority to small business concerns that participate in or conduct energy efficiency or renewable energy system R&D projects.

The NIST SBIR Program solicits energy efficiency or renewable energy system R&D projects through some of the subtopics described in this Solicitation. Further, NIST encourages innovation in energy efficiency or renewable energy system R&D by giving high priority, where feasible, to projects that conduct energy efficiency or renewable energy system R&D through technological innovation in a manner consistent with NIST’s mission. This prioritization will not interfere with the core project selection criteria: scientific and technical merit, and the potential for commercial success.

**1.05 SBIR Offeror Eligibility and Limitations**

Offerors for both Phase I and Phase II must qualify as a small business concern for research or R&D (R/R&D) purposes, as defined in Section 1.07, 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 with the small business. Primary employment with a small business precludes full-time employment with another organization.

For both Phase I and Phase II, all work must be performed by the small business concern and its subcontractors in the United States. "United States" means the fifty states, the territories and possessions of the United States, the Commonwealth of Puerto Rico, the Commonwealth of the Northern Mariana Islands, the Trust Territory of the Pacific Islands, and the District of Columbia. However, based on a rare and unique circumstance, for example, a supply or material or other item or project requirement that is not available in the United States, NIST may allow that particular portion of the R/ R&D work to be performed or obtained in a country outside of the United States. Approval by the Contracting Officer after consultation with NIST SBIR Program Manager for each such specific condition must be in writing.

NIST elects to not use the authority that would allow venture capital operating companies (VCOCs), hedge funds or private equity firms to participate in the SBIR Program.

For Phase I, a minimum of two-thirds of the research and/or analytical effort must be performed by the awardee. For Phase II, a minimum of one-half of the research and/or analytical effort must be performed by the awardee.

Unsolicited proposals or proposals not responding to subtopics in Section 9 are not eligible for SBIR awards. Only proposals that are directly responsive to the subtopics as described in this solicitation will be considered.

Potential awardees may not participate in the selection of any topic or subtopic nor in the review of proposals. All offerors, including Guest Researchers, contractors, Cooperative Research and Development Agreement (CRADA) partners and others working with NIST may only submit a proposal if they:

* Had no role in suggesting, developing, or reviewing the subtopic;
* Have not been the recipient of any information on the subtopic not available in the solicitation or other public means;
* Have not received any assistance from DOC in preparing the proposal (including any 'informal' reviews) prior to submission, excluding the Hollings Manufacturing Extension Partnership. More information on technical assistance and proposal preparation can be found on page 35.

NIST may not enter into, or continue an existing CRADA with an awardee on the subtopic of the award.

**1.06 Contact with NIST**

In the interest of competitive fairness, all oral or written communication with NIST concerning a specific technical topic or subtopic during the open solicitation period is strictly prohibited - with the exception of the public Question and Answer site located at <http://www.nist.gov/sbir>, and technical assistance from the Hollings Manufacturing Extension Partnership for proposal preparation. More information on obtaining technical assistance for proposal preparation can be found on page 35 of this solicitation. Questions will be submitted through the aforementioned NIST SBIR website and all responses will be publicly, though anonymously, posted on the web site accordingly. Questions and answers will not be accepted, or posted on FBO.

For general information on the NIST SBIR program contact:

Mary Clague
NIST SBIR Program Manager
100 Bureau Drive, Stop 2200
Gaithersburg, MD 20899

Telephone: (301) 975-4188
Email: mary.clague@nist.gov

For Solicitation information contact:

Dana Rae Graham

Acquisitions and Management Division

100 Bureau Drive, Stop 1640

Gaithersburg, MD 20899

Telephone: (301) 975-3978

Email: danarae.graham@nist.gov

**1.07 Definitions**

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.

Essentially Equivalent Work -This occurs when (1) substantially the same research is proposed for funding in more than one contract proposal or grant application submitted to the same Federal agency; (2) substantially the same research is submitted to two or more different Federal agencies for review and funding consideration; or (3) a specific research objective and the research design for accomplishing an objective are the same or closely related in two or more proposals or awards, 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 small business concern (SBC) for the performance of experimental, developmental, or research work, including products or services, funded in whole or in part by the Federal Government. For purposes of this Solicitation, NIST intends to award purchase orders and/or contracts in accordance with the Federal Acquisition Regulation.

Historically Underutilized Business Zone (HUBZone) Small Business Concern -Status as a qualified HUBZone Small Business Concern is determined by the Small Business Administration in accordance with 13 CFR Part 126.

Joint Venture - An association of persons or concerns with interests in any degree or proportion by way of contract, express or implied, consorting to engage in and carry out a single specific business venture for joint profit, for which purpose they combine their efforts, property, money, skill, or knowledge, but not on a continuing or permanent basis for conducting business generally. A joint venture is viewed as a business entity in determining power to control its management and is eligible under the SBIR and STTR Programs provided that the entity created qualifies as a "small business concern" as defined in herein.

NIST-Owned Patented Background Inventions -There is a background NIST technology, for each “TT” subtopic contained in this Solicitation, some of which are patent protected. NIST-Owned Patented Background Inventions are those patented technologies that NIST owns and has retained patent rights.
Primary Employment -Primary employment means that more than one half of the principal investigator's time is spent in the employ of the small business concern. This requirement extends also to “leased” employees (workers who are employed by a third-party leasing company) serving as the principal investigator. Primary employment with a small business concern precludes full time employment at another organization.

Research or Research and Development (R/R&D) -Any activity that is (a) a systematic, intensive study directed toward greater knowledge or understanding of the subject studied; (b) a systematic study directed specifically toward applying new knowledge to meet a recognized need; or (c) 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 SBC 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 Small Business Concern is one that, on the date of award for both Phase I and Phase II funding agreements, meets all of the following criteria:

(1) is organized for profit, with a place of business located in the United States, which operates primarily within the United States or which makes a significant contribution to the United States economy through payment of taxes or use of American products, materials or labor;

(2) is in the legal form of an individual proprietorship, partnership, limited liability company, corporation, joint venture, association, trust or cooperative, except that where the form is a joint venture, there can be no more than 49 percent participation by business entities in the joint venture;

(3) is (i) at least 51 percent owned and controlled by one or more individuals who are citizens of the United States or permanent resident aliens in the United States, (ii) at least 51% owned and controlled by another business concern that is itself at least 51% owned and controlled by individuals who are citizens of, or permanent resident aliens in the United States; or (iii) a joint venture in which each entity to the venture must meet the requirements of either (i) or (ii) of this section.

(4) has, including its affiliates, not more than 500 employees.

Control can be exercised through common ownership, common management, and contractual relationships. The term "affiliates" is defined in greater detail in 13 CFR 121.103. The term "number of employees" is defined in 13 CFR 121.106 as “all individuals employed on a full-time, part-time, or other basis.”

A business concern may be in the form of an individual proprietorship, partnership, limited liability company, corporation, joint venture, association, trust, or cooperative. Further information may be obtained at <http://www.sba.gov/size>, or by contacting the Small Business Administration’s Government Contracting Area Office or Office of Size Standards.

Socially and Economically Disadvantaged Small Business Concern - A socially and economically disadvantaged small business concern is one that is at least 51% owned and controlled by one or more socially and economically disadvantaged individuals, or an Indian tribe, including Alaska Native Corporations (ANCs), a Native Hawaiian Organization (NHO), or a Community Development Corporation (CDC). Control includes both the strategic planning (as that exercised by boards of directors) and the day-to-day management and administration of business operations. See 13 CFR 124.109, 124.110, and 124.111 for special rules pertaining to concerns owned by Indian tribes (including ANCs), NHOs or CDCs, respectively.

Subcontract - Any agreement, other than one involving an employer-employee relationship, entered by the awardee of a Federal Government funding agreement, calling for supplies or services required solely for the performance of the original funding agreement.

Women-Owned Small Business - As defined by Federal Acquisition Regulations (FAR) Part 19.001, “Women-owned small business concern means a small business concern — (a) which is at least 51 percent owned by one or more women; or, in the case of any publicly owned business, at least 51 percent of the stock of which is owned by one or more women; and (b) whose management and daily business operations are controlled by one or more women.”

**1.08 Fraud, Waste and Abuse**

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 1-800-854-8407
 Local 202-482-2495

e-mail: hotline@oig.doc.gov

**2.0 CERTIFICATIONS**

**2.01 Certification of Size, Ownership, and SBIR Program Requirements**

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.

**2.02 Research Projects with Human Subjects, Human Tissue, Data or Recordings Involving Human Subjects**

**Protection of Human Subjects**

**Research Projects Involving Human Subjects, Human Tissue, Data or Recordings Involving Human Subjects.** Any proposal that includes contractor participation in research involving human subjects, human tissue/cells, data or recordings involving human subjects must meet the requirements of the Common Rule for the Protection of Human Subjects (“Common Rule”), codified for the Department of Commerce (DoC) at 15 C.F.R. Part 27. In addition, any such proposal that includes research on these topics must be in compliance with any statutory requirements imposed upon the Department of Health and Human Services (DHHS) and other Federal agencies regarding these topics, all regulatory 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 these topics.

NIST reserves the right to make an independent determination of whether a proposer’s research involves human subjects. If NIST determines that your research project involves human subjects, you will be required to provide additional information for review and approval. If an award is issued, no research activities involving human subjects shall be initiated or costs incurred under the award until the NIST Contracting Officer issues written approval. Retroactive approvals are not permitted.

NIST will accept proposals that include research activities involving human subjects that have been or will be approved by an Institutional Review Board (IRB) currently registered with the Office for Human Research Protections (OHRP) within the DHHS and that will be performed by entities possessing a currently valid Federal wide Assurance (FWA) on file from OHRP that is appropriately linked to the cognizant IRB for the protocol. NIST will not issue a single project assurance (SPA) for any IRB reviewing any human subjects protocol proposed to NIST. Information regarding how to apply for an FWA and register and IRB with OHRP can be found at <http://www.hhs.gov/ohrp/assurances/index.html>.

Generally, NIST does not fund research involving human subjects in foreign countries. NIST will consider, however, the use of **preexisting** tissue, cells, or data from a foreign source on a limited basis if all of the following criteria are satisfied:

 (1) the scientific source is considered unique,

(2) an equivalent source is unavailable within the United States,

 (3) an alternative approach is not scientifically of equivalent merit, and

 (4) the specific use qualifies for an exemption under the Common Rule.

Any award issued by NIST is required to adhere to all Presidential policies, statutes, guidelines and regulations regarding the use of human embryonic stem cells. The DoC follows the NIH Guidelines by supporting and conducting research using only human embryonic stem cell lines that have been approved by NIH in accordance with the NIH Guidelines. Detailed information regarding NIH Guidelines for stem cells is located on the NIH Stem Cell Information website: [http://stemcells.nih.gov](http://stemcells.nih.gov/). The DoC will not support or conduct any type of research that the NIH Guidelines prohibit NIH from funding. The DoC will review research using human embryonic stem cell lines that it supports and conducts in accordance with the Common Rule and NIST implementing procedures, as appropriate.

Any request to support or conduct research using human embryonic stem cell lines not currently approved by the NIH, will require that the owner, deriver or licensee of the human embryonic stem cell line apply for and receive approval of the registration of the cell line through the established NIH application procedures: <http://hescregapp.od.nih.gov/NIH_Form_2890_Login.htm>. Due to the timing uncertainty associated with establishing an embryonic stem cell line in the NIH registry, the use of existing human embryonic stem cell lines in the NIH Embryonic Stem Cell Registry may be preferred by Offerors or current award recipients. The NIH Embryonic Stem Cell Registry is located at: <http://grants.nih.gov/stem_cells/registry/current.htm>.

An Offeror or current award recipient proposing to use a registered embryonic stem cell line will be required to document an executed agreement for access to the cell line with the provider of the cell line, and acceptance of any established restrictions for use of the cell line, as may be noted in the NIH Embryonic Stem Cell Registry.

If the proposal includes exempt and/or non-exempt research activities involving human subjects the following information is required in the proposal:

(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 Offeror linked to the cognizant IRB(s);

(4) The FWAs associated with all organizations engaged in the planned research activity 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 FWAs or IRB registrations are being applied for, that should be clearly stated.

Additional documentation may be requested, as warranted, during review of the proposal, but may include the following for research activities involving human subjects that are planned in the first year of the award:

(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 proposal submitted to NIST, if the protocol includes tasks not applicable to the proposal, or if the protocol is supported by multiple funding sources. For protocols with multiple funding sources, NIST will not approve the study without a nonduplication-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 issued, a draft of the proposed protocol may be requested.

(6) Any additional clarifying documentation that NIST may request during review of proposals to perform the NIST administrative review of research involving human subjects.

**IRB Education Documentation**

A signed and dated letter is required from the Organizational Official who is authorized to enter into commitments on behalf of the organization documenting that appropriate IRB education has been received by the Organizational Official, the IRB Coordinator or such person that coordinates the IRB documents and materials if such a person exists, the IRB Chairperson, all IRB members and all key personnel associated with the proposal. The NIST requirement of documentation of education is consistent with NIH notice OD-00-039 (June 5, 2000). Although NIST will not endorse an educational curriculum, there are several curricula that are available to organizations and investigators which may be found at: <http://grants.nih.gov/grants/guide/notice-files/NOT-OD-00-039.html>.

**2.03 Research Projects Involving Vertebrate Animals**

Any proposal that includes research involving live vertebrate animals must be in compliance with 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. In addition, such proposals must meet the requirements of the Animal Welfare Act (7 U.S.C. § 2131 et seq.), 9 C.F.R. Parts 1, 2, and 3, and if appropriate, 21 C.F.R. Part 58. These regulations do not apply to proposed research using preexisting images of animals or to research plans that do not include live animals that are being cared for, euthanized, or used by the project participants to accomplish research goals, teaching, or testing. These regulations also do not apply to obtaining animal materials from commercial processors of animal products or to animal cell lines or tissues from tissue banks.

NIST reserves the right to make an independent determination of whether your research involves live vertebrate animals. If NIST determines that your research project involves live vertebrate animals, you will be required to provide additional information for review and approval. If an award is issued, no research activities involving live vertebrate animals subjects shall be initiated or costs incurred under the award until the NIST Contracting Officer issues written approval.

If the proposal includes research activities involving live vertebrate animals the following information is required in the proposal:

(1) The name(s) of the institution(s) where the animal research will be conducted;

(2) The assurance type and number, as applicable, for the cognizant 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 Assessment and Accreditation of Laboratory Animal Care (AAALAC) should be indicated by AAALAC.]

(3) The IACUC approval date (if currently approved);

(4) If the review by the cognizant Institutional Animal Care and Use Committee (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.

Additional documentation will be requested, as warranted, during review of the proposal, but may include the following for research activities involving live vertebrate animals that are planned in the first year of the award:

(1) A signed (by the Principal Investigator) copy of the IACUC approved Animal Study Proposal (ASP);

(2) Documentation of the IACUC approval indicating the approval and expiration dates of the ASP; and
(3) If applicable, a nonduplication-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 issued, a draft of the proposed ASP may be requested.

(5) Any additional clarifying documentation that NIST may request during review of proposals to perform the NIST administrative review of research involving live vertebrate animals.

**3.0 PROPOSAL PREPARATION INSTRUCTIONS AND REQUIREMENTS**

**3.01 Proposal Requirements**

NIST reserves the right to not submit to technical review any proposal which it determines has insufficient scientific and technical information, or one which fails to comply with the administrative procedures as outlined on the Checklist of Requirements in Section 8.04. Proposals that do not successfully pass the screening criteria given in Section 4.02 will be returned to the offeror without further consideration.

The offeror 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 proposal must meet all the requirements of the subtopic in [Section 9](#book9_0) it addresses.

A proposal 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 proposal. Each proposal should be checked carefully by the offeror to ensure inclusion of all essential material needed for a complete evaluation. The proposal will be peer reviewed as a scientific paper. All units of measurement should be in the metric system.

The proposal must not only be responsive to the specific NIST program interests described in Section 9 of the solicitation, but also serve as the basis for technological innovation leading to new commercial products, processes, or servicesthat benefit the public. An offeror may submit proposals on multiple subtopics or multiple proposals on one subtopic under this solicitation. When the proposed innovation applies to more than one subtopic, the offeror must submit its proposal under the subtopic that is most relevant to the offeror's technical concept.

Proposals principally for the commercialization of proven concepts or for market research must not be submitted. Such efforts are considered the responsibility of the private sector.

The proposal should be direct, concise, and informative. Promotional and other material not related to the project shall be omitted.

**3.02 Phase I Proposal Limitations**Page length - no more than 25 pages, consecutively numbered, including the Cover Sheet (2 pages count as one – for the cover sheet only), Project Summary, technical content (which includes main text, references, resumes, other enclosures or attachments) and the Proposed Budget.

Paper size - must be standard size (21.6 cm X 27.9 cm; 8 ½" X 11").

Format - must be easy to read with a font of at least 10 point, margins should be 2.5 cm.

Supplementary material, revisions, substitutions, audio or video tapes, or computer storage media or devices will **not** be accepted.

Proposals not meeting these requirements will be returned without review.

**3.03 Phase I Proposal Submission Forms and Technical Content**

This section provides instructions for completing required forms and writing the Technical Content section. A complete proposal application must include **four copies** of each of the following:

(a) Cover Sheet (required form, see [Section 8.01](#book8_01))
(b) Project Summary (required form, see [Section 8.02](#book8_02))
(c) Technical Content (up to 22 pages)
(d) Proposed Budget (required form, see [Section 8.03](#book8_03))

**Proposals received missing any of these required items will be returned without review.**

For instructions for proposal submission, see [Section 6.0](#book6_0).

**3.03.01** [**Cover Sheet**](http://www.nist.gov/tpo/sbir/upload/cover_fy13.pdf)

Complete the Cover Sheet (Section 8.1) as page 1 of the proposal. Please ensure that required signatures on page 1b are included.

If you check ‘Yes’ on #7 of the Cover Sheet, your contact information will be provided to NIST Hollings Manufacturing Extension Partnership (MEP). You will be contacted by your local MEP to explore business-related support services that could benefit the potential of the project you proposed.

Before NIST can award a contract to a successful offeror under this solicitation, the offeror must be registered in the System for Award Management (SAM). SAM is a consolidation of Federal procurement systems including the Central Contractor Registration (CCR) database. To register, visit <https://www.sam.gov/portal/public/SAM/> or call 1-866-606-8220.

The DUNS number is a nine-digit number assigned by Dun and Bradstreet Information Services. If the offeror does not have a DUNS number, it should contact Dun and Bradstreet directly to obtain one. A DUNS number will be provided immediately by telephone at no charge to the offeror. For information on obtaining a DUNS number, the offeror, if located within the United States, should call Dun and Bradstreet at 1-800-333-0505, or access their website at <http://sbs.dnb.com>.

No award shall be made under this solicitation to a SBC without registration in SAM and a DUNS number.

Be sure to identify proposal page numbers that contain confidential information in the Proprietary Notice section at the end of the Cover Sheet.

**3.03.02** [**Project Summary**](http://www.nist.gov/tpo/sbir/upload/project_summary_fy13.pdf)

Complete the Project Summary form (Section 8.02) as page 2 of your proposal. The technical abstract should include a brief description of the problem or opportunity, the innovation, project objectives, and technical approach. In summarizing anticipated results, include technical implications of the approach and the potential commercial applications of the research. Each awardee’s Project Summary will be published on the [NIST SBIR website](http://www.nist.gov/sbir) and [www.sbir.gov](http://www.sbir.gov) and, therefore, must not contain proprietary information.

**3.03.03 Technical Content**

Beginning on page 3 of the 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. Show 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.

NIST technical support or assistance will be available to awardees in the conduct of the research only if specifically provided for in the subtopic description.

**(4)** **Related R/R&D.** Describe R/R&D that is directly related to the proposal, including any conducted by the principal investigator or by the proposer’s firm. Describe how it relates to the proposed effort, and describe any planned coordination with outside sources. The purpose of this section is to demonstrate the offeror's awareness of recent developments 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 proposal size limitations. List all other commitments that key personnel have during the proposed period of contract performance.

**(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.** The conduct of advanced research may require the use of sophisticated instrumentation or computer facilities. The offeror should provide a detailed description of the availability and location of the facilities and equipment necessary to carry out Phase I. NIST facilities and/or equipment will be available for use by awardees only if specifically provided for in the subtopic description. All related transportation/shipping/insurance costs shall be the sole responsibility of the contractor. If expressed in the subtopic description that access to NIST resources will be made available, then under mutual agreement between awardee and NIST staff, arrangements will be planned prior to NIST labs visits, samples testing or exchange, and any collaborative discussions.

**(8) Consultants and Subcontracts.** The purpose of this section is to show that: research assistance from outside the firm materially benefits the proposed effort, and arrangements for such assistance are in place at time of proposal submission.

Outside involvement in the project is encouraged where it strengthens the conduct of the research. Outside involvement is not a requirement of this solicitation and is limited to no more than 1/3 of the research and/or analytical effort in Phase I, per Section 1.05.

1. Consultant - A person outside the firm, named in the proposal 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 page count.

2. Subcontract - Similarly, where a subcontract is involved in the research, the subcontracting 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 page count.No individual or entity may serve as a consultant or subcontractor if they:

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

**(9)** **Potential Commercial Application.** 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. 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.

(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.

**(10)** **Cooperative Research and Development Agreements (CRADA).** State if the offeror 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. An Agency may not enter into, nor continue, a CRADA with an awardee on the subtopic of the award.

**(11)** **Guest Researcher.** State if the offeror or any of its consultants or subcontractors is a guest researcher at NIST, naming the sponsoring laboratory.

**(12) Cost Sharing.** Offerors may propose cost-sharing. Except where required by other statutes, NIST does not require or give preference to offerors proposing cost sharing in Phase I. NIST will not consider whether an offeror proposes cost sharing in its evaluation of proposals

**(13) Similar Proposals or Awards. WARNING --** While it is permissible, with proposal notification, to submit identical proposals or proposals containing a significant amount of essentially equivalent work for consideration under numerous Federal program solicitations, **it is unlawful to enter into funding agreements requiring essentially equivalent work.** If there is any question concerning this, it must be disclosed to the soliciting agency or agencies before award.

If a proposal submitted in response to this solicitation is substantially the same as another proposal that has been funded, is now being funded, or is pending with another Federal Agency, the proposer must so indicate on the proposal Cover Sheet and provide the following information:

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

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

(c) Title, number, and date of solicitation(s) under which a proposal was submitted or award received.

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

(e) Title of research projects.

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

If no equivalent proposal is under consideration or equivalent award received, a statement to that effect **must** be included in this section of the technical content area of the proposal and certified within the Cover Sheet.

**(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 proposal: 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 proposal information will not be counted toward the proposal pages limitation.

**3.03.04** [**Proposed Budget**](http://www.nist.gov/tpo/sbir/upload/budget_12.pdf)

Complete the Proposed Budget required form (Section 8.03) for the Phase I effort, and include it as the last page of the proposal. Verify each line item and ensure the total request is accurate and does not exceed $90,000. **The Proposed Budget must be signed**. Some items of this form may not apply to every proposal. Enough information should be provided to allow NIST to understand how the offeror plans to use the requested funds if the award is made. A complete cost breakdown should be provided giving labor rates, proposed number of hours, overhead, G&A, and profit. A reasonable profit will be allowed.

The offeror is to submit a cost estimate with detailed information for each Line Item, consistent with the offeror's cost accounting system. This does not eliminate the need to fully document and justify the amounts requested in each category. Such documentation should be contained, as appropriate, within the proposal technical content.

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

**Lines A and B, Labor.** List the key personnel and consultants by name and function or role in the project. Other direct personnel need not be named, but their role, such as “technician,” and total hours should be entered. Personnel whose costs are indirect (e.g. administrative personnel) should be included in Line G. Fringe benefits can be listed for each employee in the space provided, or they may be included within the indirect costs in Line G. The PI must be employed by the small business concern at the time of contract award and during the period of performance of the research effort. Additionally, at least 51% of the PI's time must be spent with the awardee during the contract performance.

**Line C, Equipment.** List items costing over $5,000 and exceeding one year of useful life. Lesser items may be shown in Line E. Indicate if equipment is to be purchased or leased. Where equipment is to be purchased or leased, list each individual item with the corresponding cost. The inclusion of equipment will be carefully reviewed relative to need and appropriateness for the research proposed.

**Line D, Travel.** Itemize by destination, purpose, period and cost for both staff and consultants. Budgets including travel funds must be justified and related to the needs of the project. Inclusion of travel expenses will be carefully reviewed relative to need and appropriateness for the research proposed. Foreign travel is not an appropriate expense.

**Line E, Other Direct Costs.** The materials and supplies, testing and/or computer services, and subcontracts required for the project must be identified. Specify type, quantity and unit cost (if applicable), and total estimated cost of these other direct costs.

**Line F, Total Direct Costs.** Enter the sum of Lines A through E.

**Line G, Indirect Costs.** Cite your established Overhead (OH) and General and Administrative (G&A) rate, if any. List all indirect costs (e.g. facilities, shared equipment, utilities, property taxes, administrative staff) for the period of the project. Indirect costs are costs not directly identified with a single final cost objective.

**Line H, Total Costs.** Enter the total amount of the proposed project, the sum of Lines F and G.

**Line I, Profit.** The small business concern may request a reasonable profit.

**Line J, Total Amount of this request.** Enter the sum of Lines H and I. This amount must equal the amount entered in the Cover Sheet Form.

**Line K, Corporate/Business Authorized Representative.** A signature of someone with the authority to commit the company must be given.

**4.0 METHOD OF SELECTION AND EVALUATION CRITERIA**

**4.01 Introduction**

All Phase I and II proposals will be evaluated and judged on a competitive basis. Proposals will be initially screened to determine responsiveness. Proposals passing this initial screening will be technically evaluated by NIST engineers or scientists to determine the most promising technical and scientific approaches. Each proposal will be judged on its own merit. NIST is under no obligation to fund any proposal or any specific number of proposals in a given topic. NIST may elect to fund several or none of the proposed approaches to the same topic or subtopic.

**4.02 Phase I Screening Criteria**

Phase I proposals that do not satisfy all the screening criteria shall be returned to the offeror without further review and will be eliminated from consideration for award. Proposals may not be resubmitted (with or without revision) under this solicitation. The screening criteria are:

(a) The proposing firm must qualify as eligible according to the criteria set forth in Section 1.05.

(b) The Phase I proposal must meet all of the requirements stated in Section 3.0.

(c) The Phase I proposal must be limited to one subtopic and clearly address
research for that subtopic.

(d) Phase I total proposal budget must not exceed $90,000.

(e) The feasibility research duration for the Phase I project must not exceed 6 months.

(f) The proposal must contain information sufficient to be peer reviewed as research.

**4.03 Evaluation Criteria**

Phase I proposals that comply with the screening criteria will undergo an internal, two-step scored review process. Phase II proposals are internally evaluated using Step 1 only.

**Step 1:** The proposals will be rated by NIST scientists or engineers in accordance with the following criteria:

(1) The technical approach and the anticipated agency and commercial benefits that may be derived from the research. (25 points)

(2) The adequacy of the proposed effort and its relationship to the fulfillment of requirements of the research subtopic. (20 points)

(3) The soundness and technical merit of the proposed approach and its incremental progress toward subtopic solution. (20 points)

(4) Qualifications of the proposed principal/key investigators, supporting staff, and consultants. (15 points)

(5) Consideration of a proposal’s commercial potential as evidenced by:
 a) the SBC’s record of commercializing SBIR or other research;
 b) the existence of second phase funding commitments from private sector or non-SBIR funding sources;
 c) the existence of third phase follow-on commitments for the subject of the research;
 d) the presence of other indicators of the commercial potential of the idea.
 (20 points)

Technical reviewers will base their ratings on information contained in the proposal. Offerors should be specific and clear when writing their proposals and not assume information not clearly spelled out can be inferred by the reviewer. No technical clarifications may be made after proposal submission.

After the technical review, the superior Phase I proposals will be priority ranked to ensure that the proposed research is consistent with the objectives of the laboratory's research programs (<http://www.nist.gov/laboratories.cfm>).

**Step 2 (Phase I only):** A NIST-wide selection panel will review the content of the technically superior proposals and score them based on the following evaluation factors and develop a final ranking:

(1) Proposal priority ranking resulting from Step 1.

(2) The potential of the proposed research to meet NIST program priorities (<http://www.nist.gov/director/planning/planning.cfm>).

(3) Economic impact (e.g., ability of the company to develop a commercially viable product, service or process); number and record of past performance for SBIR and STTR awards; consideration given to companies without previous SBIR awards; existence of outside, non-SBIR, funding or partnering commitments; and/or the presence of other relevant supporting material contained in the proposal that indicates the commercial potential of the idea (such as letters of support, journal articles, literature, Government publications).

(4) SBIR program priorities (manufacturing-related research; energy efficiency or renewable energy; participation by minority and disadvantaged persons and HUBZones).

Final award decisions will be made by NIST based upon ratings assigned by the selection panel and consideration of additional factors such as possible duplication of other research, and the availability of funding. In the event of a “tie” between proposals, manufacturing-related projects as well as those regarding energy efficiency and renewable energy system will receive priority in the award selection process. NIST may elect to fund several or none of the proposals received on a given subtopic. Upon selection of a proposal for a Phase I award, NIST reserves the right to negotiate the amount of the award.

**4.04 Phase II Evaluation**

During the feasibility study project performance period, all Phase I awardees will be provided instructions for preparation and submission of Phase II proposals. Phase II proposals that comply with the screening criteria as stated in those instructions will be rated by NIST scientists or engineers in accordance with the Step 1 evaluation criteria. The Step 2 evaluation is not used for Phase II proposals.

**4.05 Release of Proposal Review Information**

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

**5.0 CONSIDERATIONS**

**5.01 Awards**

NIST will award firm-fixed-price purchase orders and/or contracts to successful offerors. A firm-fixed-price purchase order or contract that allows profit, identifies a price that is not subject to any adjustment on the basis of the contractor's cost experience in performing the effort. This agreement type places upon the contractor the risk and full responsibility for all costs and resulting profit or loss. It provides maximum incentive for the contractor to control costs and perform effectively and imposes a minimum administrative burden upon both parties. NIST also does not allow any advance payments to be made on its awards. The firm-fixed-price shall be inclusive of all transportation/shipping/insurance costs for government furnished property made available for use by awardee and all deliverables/prototypes to be furnished to NIST.

Contingent upon availability of funds, NIST anticipates making a total number of approximately six (6) Phase I firm-fixed-price SBIR awards of no more than $90,000 each. The total performance period shall be no more than seven (7) months beginning on the contract 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 25 months. One year after completing the R&D activity, the awardee shall be required to report on their commercialization activities. The total period of performance for Phase II is 37 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 proposal and commercialization plan, Phase II awards will be made approximately 5 months after the completion of Phase I, contingent upon availability of funds.

This solicitation does not obligate NIST to make any awards under either Phase I or Phase II. Furthermore, NIST is not responsible for any monies expended by the offerors before awards are made.

**5.02 Reports and Deliverables**

Phase I awardees will be required to submit three progress reports and a final report. Phase I reports are due at 2, 4, 6, and 7 months after award. Phase II awardees will be required to submit four progress reports, a final report, and a commercialization report. Phase II reports are due at 2, 6, 12, 18, 24, and 36 months after award.

Phase I and Phase II progress reports will include all technical details regarding the research conducted up to that point in the project and will provide detailed plans for the next stages of the project. The acceptance of each progress report will be contingent upon appropriate alignment with the solicited and proposed milestones. 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 will be marked according to instructions provided in Section 5.04.

Final reports submitted under Phase I and Phase II shall include a single-page project summary as the first page, identifying the purpose of the research, and giving a brief description of the research carried out, the research findings or results, and the commercial applications of the research in a final paragraph. The remainder of the report should indicate in detail 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 contract \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_. 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."

The information provided in the Phase II commercialization update reports will be compiled and used as general statistics to help determine the value of the NIST SBIR Program, educate stakeholders about the outcomes and impact, and attract new entrants.

The Phase II commercialization update report shall include the following:

1. A description of the company’s efforts to further develop, commercialize and derive revenues from the technology resulting from this SBIR award. These may include but are not limited to: customer/potential customer base, overview of marketing and sales strategies, other uses of knowledge gained, partners, licensing, committed resources, market readiness, use of knowledge gained for other projects, manufacturing, and financing strategy. Also discuss difficulties, and barriers to entry.

If work has ended on the project, please provide an explanation as to why (i.e. technical objective not met, existing barriers to entry, could not obtain follow-on funding, technology not economically viable, alternative technology entered the market, or other explanation).

1. Information about any follow-on funding commitment(s) and investments to further the development and/or commercialize the Phase II technology.

If follow-on funding was not obtained, provide possible reasons (i.e. technical objective not met, technology not economically viable, alternative technology entered the market, or other explanation).

1. Details about products and /or processes being developed, used for other projects, or currently in the marketplace resulting from the SBIR project.
2. A list of any patents or published patent applications resulting from the SBIR project.
3. Sales revenue from new products or processes received from the commercialization of this SBIR project include: sales, manufacturing, product licensing, royalties, consulting, contracts, or other.

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 contracts.

Offers submitted in response to subtopics that require delivery of a prototype should state in the proposal the plan to develop and deliver the specified prototype. Notwithstanding the absence of such an explicit statement in the offeror’s proposal, delivery of the developed prototype as called for by the solicitation subtopic is required.

**5.03 Payment Schedule**

The specific payment schedule (including payment amounts) for each award will be incorporated into the purchase order and/or contract. No advance payments will be allowed.

For Phase I, one-third of the total award amount, less $5000, will be paid after acceptance and approval of each progress report. A payment of $5000 will be made after the final report is accepted.

For Phase II, one-fifth of the total award amount, less $5000, will be paid after acceptance and approval of each progress report. A payment of $5000 will be made after the commercialization report is accepted. Failure to submit the report within thirteen months of the completion of the R&D activity period for Phase II will result in a de-obligation of the $5,000.

**5.04 Innovations, Inventions and Patents**

**Proprietary Information -** Information contained in unsuccessful proposals will remain the property of the Offeror. 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 Offeror 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 Offeror 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 Offeror 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. In view of the above, Offerors are cautioned that proposals are likely to be less competitive if significant details are omitted due to the proposer’s reluctance to reveal confidential/proprietary information.

**Rights in Data Developed Under SBIR Funding Agreements** - To preserve the SBIR data rights of the awardee, the legend (or statements) used in the SBIR Data Rights clause included in the SBIR award must be affixed to any submissions of technical data developed under that SBIR award. If no Data Rights clause is included in the SBIR award, the following legend, at a minimum, should be affixed to any data submissions under that award.

These SBIR data are furnished with SBIR rights under Funding Agreement No. \_\_\_ (and subcontract No. \_\_\_ if appropriate), Awardee Name \_\_\_, Address, Expiration Period of SBIR Data Rights \_\_\_. The Government may not use, modify, reproduce, release, perform, display, or disclose technical data or computer software marked with this legend for (choose four (4) or five (5) years). After expiration of the (4-or 5-year period), the Government has a royalty-free license to use, and to authorize others to use on its behalf, these data for Government purposes, and 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. Reproductions of these data or software must include this legend.

**Copyrights** - With prior written permission of the contracting officer, the awardee normally may copyright and publish (consistent with appropriate national security considerations, if any) material developed with (agency name) support. (Agency name) receives a royalty-free license for the Federal Government and requires that each publication contain an appropriate acknowledgement and disclaimer statement.

**Patents** - Small business concerns normally may retain the principal worldwide patent rights to any invention developed with Government support. In such circumstances, the Government receives a royalty-free license for Federal Government use, reserves the right to require the patent holder to license others in certain circumstances, and may require that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically. To the extent authorized by 35 U.S.C. 205, the Government will not make public any information disclosing a Government-supported invention for a minimum 4-year period (that may be extended by subsequent SBIR funding agreements) to allow the awardee a reasonable time to pursue a patent.

**NIST-Owned Patented Background Inventions -** SBIR awards made subsequent to “TT” subtopics in this Solicitation, will, upon the license application by the awardee to a NIST licensing officer, include the grant of a non-exclusive research license to use NIST-owned patented background inventions which are specifically identified within the subtopic being awarded. SBIR offerors 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 of solicited subtopics that identify specific 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 CFR Part 404.

Any invention developed by awardee during the course of the SBIR contract period of performance is subject to the terms of discussed in the Patents section.

**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](http://www.iedison.gov/)**.**

**5.05 Cost-Sharing**
Cost-sharing is permitted for proposals under this program solicitation; however, cost-sharing is not required. Cost-sharing will not be an evaluation factor in consideration of your Phase I proposal.

**5.06 Profit or Fee**
A reasonable profit or fee is allowed.

**5.07 Joint Ventures or Limited Partnerships**
Joint ventures and limited partnerships are eligible, provided the entity created qualifies as a small business as defined in this solicitation. The small business awardee may enter into subcontracts with universities or other non-profit organizations, with the awardee serving as the prime contractor.

**5.08 Research and Analytical Work**
For Phase I, a minimum of two-thirds of the research and/or analytical effort must be performed by the proposing SBC unless otherwise approved in writing by the Contracting Officer after consultation with the agency SBIR Program Manager.

For Phase II, a minimum of one-half of the research and/or analytical effort must be performed by the proposing small business concern unless otherwise approved in writing by the Contracting Officer after consultation with the agency SBIR Program Manager/Coordinator.

**5.09 Awardee Commitments**
Upon award of a funding agreement, the awardee will be required to make certain legal commitments through acceptance of numerous clauses in Phase I funding agreement. The outline that follows is illustrative of the types of clauses to which the contractor would be committed. This list is not a complete list of clauses to be included in Phase I funding agreements, and is not the specific wording of such clauses. Copies of complete terms and conditions are available upon request.

**5.10 Summary Statements**
These are examples only and may vary depending upon the type of funding agreement used.

(1) Standards of Work. Work performed under the funding agreement must conform to high professional standards.

(2) Inspection. Work performed under the funding agreement is subject to Government inspection, evaluation, and acceptance at all times.

(3) Examination of Records. The Comptroller General (or a duly authorized representative) must have the right to examine any pertinent records of the awardee involving transactions related to this funding agreement.

(4) Default. The Government may terminate the funding agreement if the contractor fails to perform the work contracted.

(5) Termination for Convenience. The funding agreement may be terminated at any time by the Government if it deems termination to be in its best interest, in which case the awardee will be compensated for work performed and for reasonable termination costs.

(6) Disputes. Any dispute concerning the funding agreement that cannot be resolved by agreement must be decided by the contracting officer with right of appeal.

(7) Contract Work Hours. The awardee may not require an employee to work more than 8 hours a day or 40 hours a week unless the employee is compensated accordingly (for example, overtime pay).

(8) Equal Opportunity. The awardee will not discriminate against any employee or offeror for employment because of race, color, religion, sex, or national origin.

(9) Affirmative Action for Veterans. The awardee will not discriminate against any employee or application for employment because he or she is a disabled veteran or veteran of the Vietnam era.

(10) Affirmative Action for Handicapped. The awardee will not discriminate against any employee or offeror for employment because he or she is physically or mentally handicapped.

(11) Officials Not To Benefit. No Government official must benefit personally from the SBIR funding agreement.

(12) Covenant Against Contingent Fees. No person or agency has been employed to solicit or secure the funding agreement upon an understanding for compensation except bona fide employees or commercial agencies maintained by the awardee for the purpose of securing business.

(13) Gratuities. The funding agreement may be terminated by the Government if any gratuities have been offered to any representative of the Government to secure the award.

(14) Patent Infringement. The awardee must report each notice or claim of patent infringement based on the performance of the funding agreement.

(15) American Made Equipment and Products. When purchasing equipment or a product under the SBIR funding agreement, purchase only American-made items whenever possible.

**5.11 Additional Information**

This program solicitation is intended for informational purposes and reflects current planning. 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 offeror to submit certain organizational, management, personnel, and financial information to assure responsibility of the offeror.

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

This program solicitation 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 proposal mechanisms. Unsolicited proposals will not be accepted under the SBIR Program in either Phase I or Phase II.

If an award is made pursuant to a proposal submitted under this SBIR Program solicitation, a representative of the contractor 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, lies with the management of the organization receiving an award.

NIST may provide technical assistance to awardees as allowed by legislation.

**5.12 Technical Assistance for Proposal Preparation and Project Conduct**

Offerors 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 contact an MEP center, call 1-800-MEP-4-MFG (1-800-637-4634) or visit MEP‘s website at <http://www.mep.nist.gov>**.**

MEP Centers are also prepared to provide referrals to state and local organizations offering resources and technical assistance to all NIST SBIR Offerors after award solicitations have been announced. If you would like your local MEP Center to contact you, please check the appropriate box on page 1 of the Cover Sheet.

**6.0 SUBMISSION OF PROPOSALS**

**6.01 Deadline for Proposals**

**Deadline for Phase I SBIR proposal receipt is 3:00 pm ET on Monday, February 25, 2013 at the Contracts Office address below.**

NIST does not accept electronic submission of proposals. NIST will not evaluate proposals received after the stated deadline or that do not adhere to the other requirements of this solicitation (see checklist in section 8.04). [Federal Acquisition Regulation](https://www.acquisition.gov/Far/farqueryframe.html)(FAR 52 215-1) regarding late proposals shall apply.

All Offerors should expect delay in delivery due to added security at NIST. It is the responsibility of the Offeror to make sure delivery is made on time.

Because of the heightened security at NIST, USPS, FED-EX, UPS or similar-type service is the preferred method of delivery of proposals.

Offerors are cautioned to be careful of unforeseen delays, which can cause late arrival of proposals at NIST, resulting in them not being included in the evaluation procedures.

No information on the status of proposals under scientific/technical evaluation will be available until formal notification is made.

**6.02 Proposal Submission**

**Four (4) copies of the Proposal Package as defined in Section 3.03 should be delivered to NIST prior to the deadline (3:00 pm ET on Monday, February 25, 2013).**

**If courier delivered,** submit the Proposal Packages to:

National Institute of Standards and Technology
Acquisitions and Management Division
Attn: Dana Rae Graham, NIST-13-SBIR
100 Bureau Drive STOP 1640 Building 301, Room B125
Gaithersburg, MD 20899-1640

Telephone: (301) 975-3978

**If hand delivered**, 24-hours notice must be given to the NIST Contracts Office prior to delivery. All Offerors must contact Dana Rae Graham at 301-975-3978 or danarae.graham@nist.gov to arrange hand delivery of proposal packages. Proposals may not be dropped off at the Visitor Center. **Hand delivery will only be accepted through prior arrangement**.

 Photocopies will be accepted.

Acknowledgment of receipt of a proposal by NIST will be made. All correspondence relating to proposals must cite the specific proposal number identified on the acknowledgment.

Secure packaging is mandatory. NIST cannot process proposals damaged in transit. All 4 copies of the proposal must be sent in the same package. Do not send separate "information copies," or several packages containing parts of a single proposal, or two packages of 4 copies of the same proposal.

Do not use special bindings or covers. Staple the pages in the upper left hand corner of each proposal. Separation or loss of proposal pages cannot be the responsibility of NIST.

**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](http://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**

Click on the links below to access the required forms.
**8.01** [Cover Sheet](http://www.nist.gov/tpo/sbir/upload/cover_fy13.pdf)(2 pages) in pdf format.
**8.02** [Project Summary](http://www.nist.gov/tpo/sbir/upload/project_summary_fy13.pdf)in pdf format.
**8.03** [Proposed Budget](http://www.nist.gov/tpo/sbir/upload/budget_fy13.pdf) in pdf format.

**8.04 Checklist of Requirements**Please review this checklist carefully to assure that your proposal meets the NIST requirements. Failure to meet these screening requirements will result in your proposal being returned without consideration. **Four copies of the proposal must be received by 3:00 pm ET on Monday, February 25, 2013.**(1) The [Cover Sheet](http://www.nist.gov/tpo/sbir/upload/cover_fy13.pdf)  (both pages combined count as one toward page count) has been completed and is page 1 of the proposal. Required signatures on page 1-b are included.

(2) The [Project Summary](http://www.nist.gov/tpo/sbir/upload/project_summary_fy13.pdf)is page 2 of the proposal. The abstract contains no proprietary information.

(3) The Technical Contentof the proposal begins on page 3 and includes the items identified in Section 3.03.03of the solicitation. The technical content section of the proposal is limited to 22 pages in length.

(4) The [Proposed Budget](http://www.nist.gov/tpo/sbir/upload/budget_fy13.pdf) has been completed, **including signature**, and is the last page of the proposal. The proposal budget is for $90,000 or less. No more than one-third of the budget is allocated to consultants and/or subcontractors.

(5) The entire proposal, including forms and the technical content, is 25 pages or less in length.

(6) The proposal is limited to only one of the subtopics in Section 9.

(7) The proposal contains only pages of standard size (21.6cm X 27.9cm or 8 ½" X 11").

(8) The proposal contains an easy-to-read font (font of point size 10 or larger) with no more than 6 lines per inch, except as a legend on reduced drawings, but not tables.

(9) The P.I. will be employed by the company at least 51% time during the award period.

Offerors are cautioned to be careful of unforeseen delays that can cause late arrival of proposals, with the result that they **WILL NOT** be forwarded for evaluation.

Potential offerors are advised to sign up within [http://www.fedbizopps.gov](http://www.fedbizopps.gov/)to receive notification of any amendment to the solicitation that may be released after opening date. Also, potential offerors 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 Solicitation open period.

**9.0 RESEARCH TOPIC AREAS**

The research topic areas are 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 Cybersecurity**

**9.01.01.77-TT Bragg Grating Enhanced Narrowband Single Photon SPDC Source**

Quantum communications holds great potential as a solution for ultimate cyber security – security based on the quantum mechanical properties of single particles, such as photons, rather than on complex mathematical algorithms. An unmet need in the area of quantum communications is a robust, simple and effective narrow bandwidth source of entangled photons. A narrow bandwidth source is essential to enable quantum memory and quantum repeaters – the building blocks of secure quantum computing and quantum communications networks. Current implementations of narrow bandwidth entangled photons are complex and expensive and have little potential as mainstream commercial devices. Recently, researchers at NIST published theoretical details of a technique to generate narrow bandwidth entangled photon pairs by way of Bragg-grating enhanced spontaneous parametric down conversion (SPDC). This novel technique incorporates an internal Bragg-grating onto a nonlinear optical chip such as periodically poled lithium niobate (PPLN) or periodically poled potassium titanyl phosphate (PPKTP). The internal resonance of the Bragg grating will narrow the SPDC line width to sub-GHz – suitable for atomic interactions and quantum memory. This singular device, when implemented, will be simple, compact, robust, inexpensive and effective. Because of these characteristics, this Bragg grating device would have a major impact in the research and development of secure quantum systems and would represent a leap forward toward the application of quantum systems beyond the laboratory. NIST is seeking proposals from US industry to further develop such devices in order to assess their suitability for commercialization.

The goal of this project is to develop the facilities to produce reliable and repeatable lithographed Bragg gratings onto non-linear crystals used for SPDC photon pairs generation. SPDC has been an engine in the advancement of quantum based research. However, it is naturally a broadband source of several hundreds of GHz or even THz. This technique would represent a very significant development in that technology by lossless reduction of the linewidth to sub-GHz in a compact and simple device. The theoretical study has been completed by NIST and we are confident that the approach is valid. In addition, lithography is an established technology and there is an expectation that the company will easily implement a test case during Phase I. The real challenge and work will be in Phase II when the process will be refined for optimal effect. We are now anxious to work with a small business, competent in the area of lithography and familiar with the physical properties of PPLN and PPKTP, to incorporate a Bragg-grating onto the chip. The initial expected outcome would be a significant (nearly a single order of magnitude) reduction in linewidth. This initial goal will provide confidence in the concept and provide insight into the requirements for further improvement. Optimization and refinement of facilities, processes and techniques will further reduce the linewidth to near a GHz – the ultimate goal. A study of the optimal specifications for the lithographed grating (e.g. the depth into the crystal for specific down conversion) will ensure a repeatable and reliable process suitable for commercialization.

Phase I Activities:

* The company will, if and as needed, upgrade their facilities to incorporate a Bragg-grating onto a non-linear optical chip.
* One such Bragg-grated chip will be developed as a test case. (One underlying chip upon which the Bragg grating is to be incorporated will be provided by NIST; more are available for external purchase.)
* Extensive testing of the device will be required on both the optical and physical properties.
* Finally, a complete feasibility study will be done to identify the obstacles to optimum performance of the produced devices in comparison with the theoretical limitations; and a set of concrete proposals to overcome these obstacles will be developed. The go-no go decision will be based on a significant (near 1 order of magnitude) narrowing observation.

Phase I Deliverables:

1. Demonstration of expertise and facilities capable of incorporating a Bragg grating onto a non-linear crystal. Ideally, a tour or demonstration will be provided early in Phase I.
2. Implement Bragg-grating onto at least one test case chip (one such underlying chip will be provided by NIST for this effort) with a demonstration of significant (near >1 order of magnitude) reduction of linewidth. A single chip will be provided to NIST.
3. Feasibility report identifying the obstacles to sub-GHz linewidth reduction. If considered feasible, concrete proposals to overcome these obstacles.

Phase II Activities:

* If accepted for Phase II, the initial task will be to address the obstacles to optimum performance according to the proposals and feasibility report from Phase I, and to produce at least two Bragg-grating chips with narrowing to near 1GHz or better. (Two underlying chips will be provided by NIST and returned to NIST following incorporation of the Bragg-grating.)
* Once successfully achieved, a suitable scheme will be developed to analyze and test the repeatability and robustness of the Bragg-grating chip implementation, including a technique to measure of the linewidth of the output photon pairs.
* Finally, a detailed final report will be produced.

Phase II Deliverables:

1. Demonstration of expertise and facilities capable of incorporating a Bragg grating onto a non-linear crystal for near 1 GHz SPDC and capable of testing for production repeatability.
2. Implementing Bragg-grating onto at least two chips (two underlying chips will be provided) with testing to demonstrate reduction of linewidth to near 1 GHz or better. Two completed Bragg-grating chips will be provided to NIST.
3. Final report.

It is expected that this project will involve consultation and input from NIST researchers who developed the technology upon which this follow-on work is based. The company will have access to the NIST campus to perform any required testing at a mutually agreed-to time, since NIST has advanced capability in single photon detection which may be difficult to obtain elsewhere. Specifically, the company will have access to building 222, room B219 (quantum communications laboratory).

References:

1. Li Yan, Lijun Ma, and Xiao Tang, "[Bragg-grating-enhanced narrowband spontaneous parametric down-conversion](http://www.opticsinfobase.org/viewmedia.cfm?uri=oe-18-6-5957&seq=0)", Optics Express, Vol. 18, No. 6, 5957 (2010).
2. Li Yan, Lijun Ma, and Xiao Tang, ["Narrow-band photon pairs generated from spontaneous parametric down conversion in a Bragg-grating enhanced waveguide](http://spiedigitallibrary.aip.org/getpdf/servlet/GetPDFServlet?filetype=pdf&id=PSISDG007815000001781511000001&idtype=cvips&prog=normal)", Proc. of SPIE Vol. 7815, page 781511.

**9.01.02.77-R Comparison of Privacy-enhancing Technologies and Features**

A key finding of NIST’s workshop last December (2011) on Privacy Enhancing Cryptography (<http://www.nist.gov/itl/csd/ct/pec-workshop.cfm>) was that this technology, while both sound from a cryptographic perspective and exciting from a privacy perspective – including alignment with the National Strategy for Trusted Identities in Cyberspace (NSTIC) – faced significant challenges in winning adoption in the marketplace due to concerns about usability and commercial viability.

The NSTIC National Program Office (NPO) recently funded three pilots that will be testing privacy-enhancing cryptography in different use cases and settings as well as two pilots that use alternative non-cryptographic based privacy features. In addition, the NPO has been involved in the development of a project to pilot a Federal Cloud Credential Exchange (FCCX) which also will leverage privacy-enhancing cryptography. A key unmet need is an independent and objective assessment of these pilots that compares and contrasts the usability and privacy performance of the different approaches taken in each pilot, as well as the successes and difficulties each pilot faced in its tests in the marketplace. In addition, an analysis of the NSTIC pilots could provide valuable information to the NIST Information Technology Laboratory (ITL) to help determine gaps in standards and research, particularly for new and advanced technologies.

Project Goals:

1. Perform an independent analysis and comparison of each of the pilots, looking at the usability and privacy performance of the different approaches taken in each pilot.
2. Perform an independent analysis and comparison of each of the pilots, looking at the successes and difficulties each pilot faced in its tests in the marketplace.
3. Design and, if feasible, conduct usability and performance tests for privacy technologies and features for selected pilots.
4. Perform a gap analysis of existing standards and research, in order to help identify requirements for identity management efforts (e.g., standards and research work in security, interoperability, usability, etc.).

Phase I Activities:

1. The awardee will perform analysis and evaluation activities to document the different approaches used by the NSTIC pilots. Analysis of those pilots will be performed against a set of criteria and attributes to compare the various approaches.
2. The awardee will perform a gap analysis of existing standards and research, in order to help identify requirements for identity management efforts (e.g., standards and research work in security, interoperability, usability, etc.).

Phase I Deliverables:

1. Document that outlines the evaluation approach and methodology including methods for comparison and what attributes will be compared.
2. An annotated outline for the Comparative Evaluation Findings Report.
3. Comparative Evaluation Findings Report to include: results of the independent analysis and comparison of each of the three NSTIC pilots that test privacy- enhancing cryptography, looking at the usability and performance as well as the successes and difficulties; recommendations on how privacy-enhancing cryptography (and the business models that support its deployment) can best be tailored to achieve future success in the commercial marketplace.

4. A document that outlines gaps in existing standards and research with regard to identity management, including a description of the methodology used to identify the gaps.

Phase II Activities:

1. Expand analysis and comparison to include privacy-enhancing technologies in the FCCX Pilot.
2. Design and, if feasible, conduct usability and performance testing on the technologies in the FCCX pilot.

3. Compare the relative privacy benefits of the projects’ (NSTIC and FCCX) privacy- enhancing technology vs. the NSTIC pilots that did not use privacy- enhancing technologies.

Phase II Deliverables:

1. A document that outlines the evaluation approach and methodology including methods for comparison and what attributes will be compared.
2. A document that outlines the usability and performance test methodology.
3. Updated Comparative Evaluation Findings Report on FCCX providing a benchmark for use by other developers of privacy enhancing technologies.
4. An annotated outline for the Final Testing Report.

5. Final Testing Report including: results of usability and performance testing on the FCCX pilot; comparison of the relative privacy benefits of the projects’ technology vs. the NSTIC pilots that did not use privacy enhancing technologies; recommendations based on the results of the testing and updated comparison on how privacy-enhancing cryptography (and the business models that support its deployment) can best be tailored to achieve future success in the commercial marketplace and what future activities both NIST and the new IDESG should undertake to support these efforts.

NIST is available for consultation and input, discussion, as well as possible work collaboration.

References:

1. NIST’s workshop last December (2011) on Privacy Enhancing Cryptography (<http://www.nist.gov/itl/csd/ct/pec-workshop.cfm>).
2. NIST National Strategy for Trusted Identities in Cyberspace website (<http://www.nist.gov/nstic/>).

**9.01.03.77-R Development of an SCAP Validation Tool with APIs**

NIST created the Security Content Automation Protocol (SCAP) Validation Program in support of OMB mandates requiring industry and government information technology providers to use SCAP validated products for verifying and continuously monitoring configurations as part of FISMA activities. The current testing methods used for measuring the correctness and effectiveness of SCAP products are largely manual and laborious; thus limiting the ability to maintain comprehensive validation testing as the number of SCAP test cases increases. Tools supporting automated testing methods are paramount to cost-effective, rigorous and comprehensive testing of commercial security automation products. A robust testing tool would provide vendors with the ability to self-assert product support of SCAP capabilities, supply NVLAP accredited laboratories with the tooling needed to perform formal SCAP validation testing as required by the OMB mandate, and end users a means to perform their own conformance testing of commercial security automation tools as part of the acquisition process. Such a tool advances NIST’s goals by supporting the calibration of security automation tools using SCAP reference materials and by providing an automated solution for measuring the correctness and effectiveness of security automation tools. The tool will increase the overall assurance level for SCAP conformance testing, while decreasing error prone manual processes and required timeframes when performing tests, resulting in lower overall testing costs.

The following project goals seek to foster the development of a validation tool that enables consistent, automated, efficient, reliable and robust vendor self-assertion, formal lab testing, and end user conformance testing.

* Create platform agnostic software that consumes test content, test environment parameters, and expected results. Platform issues relating to supporting a variety of hardware, operating system and applications must be addressed using an extensible and sustainable approach.
* Automate configuration of test environment, execution of test content, and comparison of actual results to expected results.
* Provide language independent APIs that support integration of the validation tool into other related software (e.g. workflow management, testing databases).
* Support parallel or distributed execution of the test content.
* Develop functional incremental tool releases using agile software development methods.
* Complete development with the release of an open source, production-ready validation tool.

Phase I Activities:

* Plan tool design.
* Develop functional requirements.
* Create design document.
* Mockup the user interface.
* Develop implementation plan.
* Develop the data schema for inputs and outputs.

Phase I Deliverables:

* Design document that includes description of tool functionality, APIs, user interface mockups, and expected inputs and outputs, and use cases. Develop data schema for inputs and outputs, and code mockups for the user interface.
* Implementation plan that includes high level approach, software development methodology, and technology stack (e.g., programming language, open source libraries, target operating systems).

Phase II Activities:

* Create project plan with functional prototype, public beta release, and production release milestones.
* Develop incremental software builds.
* Deliver functional prototype.
* Demonstrate the functional prototype to NIST.
* Release public beta version with draft documentation.
* Collect feedback on public beta release.
* Address comments on public beta release.
* Create user and API documentation.
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* Release production-ready validation tool.

Phase II Deliverables:

* Project plan with milestones for functional prototype release, public beta release, and production-ready release with user and API documentation.
* Functional prototype release.
* Public beta release.
* Production-ready release.
* End user documentation.
* API documentation.

NIST is available for weekly consultation, input, and discussion.

References:

1. SCAP Validation Program website, <http://scap.nist.gov/validation/index.html>.

2. NIST IR 7511 Revision 3, <http://csrc.nist.gov/publications/PubsNISTIRs.html#NIST-IR-7511>.

**9.01.04.77-R Enabling Secure BIOS on Enterprise Systems**

In April 2011, NIST issued Special Publication 800-147, “*BIOS Protection Guidelines*” with minimum requirements to protect critical boot firmware on personal computers, called the Basic Input/Output System (BIOS), from unauthorized modifications [1]. These guidelines were extended to also cover server-class systems [2]. Attacks on BIOS are a growing threat due to its critical position in computer systems. These attacks could disable a computer system or place powerful malicious software on a computer that would be difficult to detect.

Major computer vendors have aggressively implemented secure BIOS in their new products, and have also issued firmware updates to many of their existing products to add these protections. When implemented and configured appropriately, these protections are capable of blocking known threats to BIOS, including the Mebromi malware discovered in September 2011 [3]. However, the adoption of BIOS protections by users and administrators has been hampered by the lack of easy-to-use tools and processes for centrally managing BIOS in large organizations. Common configuration and patch management solutions used by large organizations to update operating systems and applications are not designed to manage BIOS, requiring administrators attempting to push BIOS updates to develop their own complicated workarounds to achieve this goal.

Organizations have invested significant resources in their current configuration and patch management solutions. However, new tools could be developed that integrate with these solutions and extend their functions to more easily manage BIOS. These tools would fill a critical need of the public and private sectors and would promote NIST standards and guidelines that combat the threat to BIOS.

This project will develop tools and processes intended to facilitate central management of BIOS. These tools will need to integrate with existing configuration and patch management tools and provide system administrators with the ability to push BIOS updates to computers and set critical security settings, including BIOS protection features.

Computer vendors currently supply their customers with tools for updating and configuring BIOS on their systems. However, these tools are vendor-specific, and typically not designed to be used with central management processes, a critical feature for organizations with large numbers of machines. Unlike operating system and application updates, BIOS updates must be deployed on a model-by-model basis, as different computer models will have different BIOS versions. The mapping from computer model to BIOS version is typically done manually today, but it should be possible to automate most of this process.

The existing vendor-supplied tools provide the necessary mechanisms for updating and managing BIOS once the computer model specific BIOS is identified and the corresponding tool is installed onto the machine. The existing configuration patch management solutions provide the necessary mechanisms for deploying and running these tools on organizations’ centrally managed machines. However, the critical gap is the link between these two systems. System administrators need a tool that integrates with their existing configuration and patch management solutions to select the proper vendor and model-specific BIOS tool.

To deal with the heterogeneous computer environments found in large organizations, the tools developed from this project should work with a variety of configuration and patch management solutions as well as computers from a wide range of vendors.

These tools, if developed, commercialized and adopted by organizations, should greatly facilitate adoption of the BIOS protections currently supported, but frequently unused, in computer systems.

Phase I Activities:

Feasibility Study

* Research current systems supporting BIOS protections and any tools supplied by the computer vendor to manage or update the BIOS.
* Develop proof-of-concept tools and scripts that configure and use the vendor-supplied tools depending on the computer model.

Phase I Deliverables:

* A survey of products and platforms supporting BIOS protections.
* Proof-of-concept tools and scripts for updating BIOS on systems from two or more vendors.
* Proof-of-concept tools and scripts for enabling BIOS protections on systems from two or more vendors.

Phase II Activities:

Development of Tools and Processes for BIOS Management

* Research capabilities of common configuration and patch management solutions.
* Extend the proof-of-concept tools and scripts and integrate them with two or more configuration and patch management solutions.

Phase II Deliverables:

* Tools and scripts for updating BIOS and configuring security settings.
* Documentation describing how to integrate these tools with configuration and patch management solutions, along with proposes processes for deploying these tools in enterprise environments.
* One or more demonstrations of the tools developed by the awardee, using the BIOS update and management processes provided in their documentation. These demonstrations may be provided at a public event or on video.

Technical staff in the Computer Security Division (CSD) would be available to consult with the awardee on this project. CSD has been working closely with government and industry on BIOS protections for the past 18 months. We can assist the awardee with initial research activities by providing them with lists of computer systems known to support BIOS protections, we can connect them with computer vendors supporting BIOS protections, and we can coordinate with industry partners with experience deploying BIOS updates.

References:

[1] NIST SP 800-147, *BIOS Protection Guidelines*. April 2011. <http://csrc.nist.gov/publications/nistpubs/800-147/NIST-SP800-147-April2011.pdf>.

[2] NIST SP 800-147, *BIOS Protection Guidelines for Servers (Draft)*. July 2012. <http://csrc.nist.gov/publications/drafts/800-147b/draft-sp800-147b_july2012.pdf>.

[3] Symantec, *Trojan.Mebromi*. September 2011. <http://www.symantec.com/security_response/writeup.jsp?docid=2011-090609-4557-99>.

**9.01.05.68-R Single-Photon Avalanche Diodes with > 95 % Efficiency**

Recent advances in quantum communications and quantum random number generation have identified the critical need for detectors with single-photon-detection efficiency above bounds that are determined by information theory. Additional losses in any preceding optical components require that the efficiency of the subsequent detectors be even higher. Devices of this type may be used in verifiable random number generation, a critical need for cryptography and cyber security. Detectors with single-photon detection efficiency above 95 % are generally considered suitable for these applications, though higher efficiency is better. To date, the only candidates that meet this requirement operate at cryogenic temperatures, which significantly increases the complexity and cost of any cryptographic apparatus based on such processes.

Recent advances have demonstrated that silicon single-photon avalanche diodes can achieve detection efficiencies that exceed 80 % at some wavelengths, while maintaining relatively low noise (less than 1 kHz dark count rate). These advances are promising, and suggest that it may be possible to achieve near unity single-photon detection efficiency in a compact, low-cost device that requires only thermoelectric temperature control. Such a device would be a critical component in the development of a small-form-factor quantum-random-number-generation equipment. NIST has an interest in quantum random number generation for cyber-security and selective disclosure protocols, as well as an ongoing commitment to quantum optics research and devices that enable quantum information processing.

The project should result in the development, demonstration, and delivery of single-photon avalanche diodes with single-photon detection efficiency that exceeds 95 %. In addition, noise is an important concern for detectors for cyber-security applications. To this end, the intrinsic dark count rate of the devices must be below 10 kHz, while the timing resolution must be better than 1 ns (full-width at half maximum), or, equivalently, the per-gate dark count rate should not exceed 10^-5. There are no requirements on the wavelength at which the devices operate (Offerors are free to pick a fixed wavelength) or the maximum count rate. To allow efficiency optical coupling, the device’s diameter should be larger than 50 micrometers. Devices that meet all these requirements would represent a significant advance in single-photon detection technology, and would benefit not only cyber-security and quantum information applications, but also the more conventional applications of high-efficiency single-photon detectors such as fluorescence spectroscopy and LIDAR.

Phase I Activities:

* Design of silicon single-photon avalanche diodes with > 95 % single-photon detection efficiency.
* Fabrication of silicon single-photon avalanche diodes with > 95 % single-photon detection efficiency.
* Packaging of single-photon avalanche diodes with > 95 % single-photon detection efficiency.
* Testing and characterization of single-photon avalanche diodes with > 95 % single-photon detection efficiency.

Phase I Deliverables:

Qty. 10 single-photon avalanche diodes with > 95 % single-photon detection efficiency in a hermetically sealed package with dual-stage thermoelectric cooler.

Phase II Activities:

* Design of silicon single-photon avalanche diodes with > 98 % single-photon detection efficiency.
* Fabrication of silicon single-photon avalanche diodes with > 98 % single-photon detection efficiency.
* Packaging of single-photon avalanche diodes with > 98 % single-photon detection efficiency.
* Testing and characterization of single-photon avalanche diodes with > 98 % single-photon detection efficiency.

Phase II Deliverables:

Qty. 10 single-photon avalanche diodes with > 98 % single-photon detection efficiency in a hermetically sealed package with dual-stage thermoelectric cooler.

NIST has extensive experience in characterizing single-photon avalanche diodes, and can work collaboratively to test and characterize the devices fabricated and packaged under this project.

**9.02 Manufacturing**

**9.02.01.73-R Advanced Tactile Sensing Technology for Robotic Hands**

Industrial robot systems currently have far less dexterity than humans. This deficiency has led to the industry practice of custom-building robot systems with custom end-effectors and fixturing for each task, which greatly increases product changeover time and cost. Next-generation robot systems will be more flexible with multiple degree of freedom “robotic hands” and will provide levels of versatility and control closer to that of a human. These robotic hands have the potential reduce the need for customized end-tooling and careful grasp programming, allowing manufacturers to apply robots to a broader set of tasks than is currently possible today. Robotic hands are often equipped with tactile sensing though the use of pressure sensor arrays at the fingertips, distal and proximal phalanx and palm regions and can be used to sense object grasp contact properties as well as part slippage though force measurement. These tactile sensor arrays are somewhat limited when compared to the sensing capabilities in the human hand.

NIST is currently involved in a research and development project that will develop metrics, artifacts, and methods to measure the characteristics of grippers and robotic hands that allow them to manipulate parts, such as grip stability, surface cohesion, and obstruction stability. To do this, NIST will be utilizing off-the-shelf robotic hands some of which incorporate force based tactile sensing technology. In order to support a wider range of metrics, NIST is looking for next generation tactile sensing technologies that in addition to force, can also sense properties such as deformation, vibration, and temperature. Ideally such a sensor system could be integrated onto a variety of robotic hands.

The awardee of this SBIR subtopic will develop advanced tactile sensing technology as well as associated metrics and test methods that demonstrate the potential for use with a robotic hand in an industrial manufacturing environment. The advances shown in this technology will in addition to measuring force at a point of contact, be able to resolve a force vector acting at the point. This advanced sensing technology will mimic human touch capabilities which include the detection of slip and the discrimination of grasp object geometry (e.g., edges, corners, and flat surfaces), object compliance, and thermal properties.

Phase I Activities:

* Develop the tactile sensing technology to measure both force and deformations (and optional additional sensing technologies such as vibration and temperature) that can potentially withstand a manufacturing environment.
* Develop performance metrics, test methods, and industrial artifacts to support testing of the technology.

Phase I Deliverables:

* A set of three distal phalanx tactile sensor systems sensing at minimum force and displacement integrated onto NIST’s Schunk Dexterous Hand utilizing the existing CAN bus interface.
* A documented set of metrics, test methods and associated artifacts representative of parts from a manufacturing setting being manipulated by the distal phalanx regions of a robotic hand.

Phase II Activities:

* Refine the technology based on performance testing and extend implementation to include advanced tactile sensing units for the middle phalanx, proximal phalanx, and palmar sensing.

Phase II Deliverables:

* A set of distal phalanx, middle phalanx, proximal phalanx, and palmar region advanced tactile sensing components to support the Schunk Dexterous Hand.
* A documented set of metrics, test methods and associated artifacts extended to support grasping capabilities utilizing the additional tactile sensing components.

NIST will be willing to collaborate with the awardee.

**9.02.02.63-R Angularly Sensitive Detectors for Transmission Scanning Electron Microscopy**

The NIST Applied Chemicals and Materials Division seeks to significantly extend the capabilities of the scanning electron microscope (SEM), a tool considered invaluable for characterizing materials and products in numerous forms of manufacturing. Examples range from extremely fine-scale structures found in nanoparticle production and semiconductor processing to large-scale structures used for transportation and infrastructural applications. The efficiency and quality of all manufactured products depends intimately on the ability of engineering materials to perform their intended function. Those functions are a direct result of the properties imparted upon each material due to the arrangement of their atoms over dimensional scales from sub-nanometer to several hundreds of micrometers. It is therefore critical to product manufacturing and reliability that the microscopic structure of materials be precisely measurable over those size scales.

An emerging area of material characterization makes use of the detection of electrons that have transmitted through specimens within an SEM, in order to significantly improve spatial resolution and image contrast over many conventional SEM and transmission electron microscope (TEM) methods. This approach makes use of some operational principles analogous to those used in scanning transmission electron microscopy (STEM), and is therefore sometimes termed “STEM-in-SEM” (see, for example, detector product sold by Carl Zeiss or KE Developments). At NIST, we are concurrently developing SEM-based technologies that make use of transmitted electrons in ways different from STEM imaging, resulting in a broader characterization approach we call transmission SEM, or t-SEM.

An opportunity exists to greatly strengthen the t-SEM approach to material characterization, through the development of electron detectors that are capable of directly producing bright-field and dark-field images with improved angular selectivity as well as transmission electron diffraction patterns. Successful development of such detectors for SEMs in manufacturing environments would result in two major benefits to manufacturing: (1) a host of powerful analytical material characterization methods would be brought within reach for those presently without access to TEMs, due to budgetary or personnel constraints, and (2) a new, broader spectrum of measurements will be achievable with relatively inexpensive modifications or add-ons to existing SEM investments, as compared to state of the art TEM purchases. As a result, manufacturers may perform detailed measurements for product optimization, as well as meaningful root-cause failure analyses, both from the key perspective of structure of engineering materials.

Project Goals:

1. Direct electron detection technology that can produce bright-field (BF) images, dark-field (DF) images, and transmission electron diffraction spot/ring patterns. The images and diffraction patterns would be ideally captured using the same detector, though not necessarily concurrently.
2. Direct electron detection technology that is angularly sensitive, i.e., that can produce a BF or DF image from a pre-defined selection of scattering angles, either with or without use of the transmission electron diffraction pattern.
3. Direct electron detection technology that can be either integrated with existing SEM amplification and image output electronics, or readily coupled with external electronics and computer systems for signal amplification and data acquisition.

Phase I Activities:

* Choose or develop a method to directly detect electron scattering *through* a thin (~ 100 nm or less) piece of Si, Al, Cu, or Ni, with the SEM operating at 20 kV or higher, with an incident beam current of no greater than 1 nA. The method must be scalable to a final form that enables collection of a diffraction pattern or image with total scattering angle of 15° to 20° or more (enough to observe several diffraction orders away from the straight-through beam in one of the materials above).
* Design a method to select a small subset of the scattering into the detector, i.e., a means by which one may either “aperture off” a region of the detector, or to individually address a small number of channels in an array-type of detector.
* Integrate the proposed detection method and angular selection control to show that projected angular regimes as small as approximately 0.5° to 1.0° can still be used to as the basis for subsequently forming an image.

Phase I Deliverables:

* Demonstrate this method through analytical means or through a simple experiment. The signal may be any form of electron scattering through the specimen.
* Produce a detailed schematic of how angular selection can take place practically. For example, through individual element addressing in a CCD chip or through precise x-y positioning of a mechanical aperture above a CCD chip or scintillator.
* Demonstrate either analytically or through a simple experiment that a current as low as 10 pA to 100 pA (or lower) can be detected from the angular subset (this is an estimate of the currents available within a single transmission electron diffraction spot). For example, through a subset created through individual element addressing in a CCD chip or through precise x-y positioning of a mechanical aperture above a CCD chip or scintillator.

Phase II Activities:

* Construct an angularly selective detector based on the feasibility demonstrated in Phase I.
* Design and construct a method by which the detector is synchronized with the scanning action of the incident SEM beam – this forms the basis for image formation. The detector must also be used to collect a diffraction pattern. This activity includes deciding upon integration with existing SEM amplification and image output electronics, or readily coupled with external electronics and computer systems for signal amplification and data acquisition.

Phase II Deliverables:

* Demonstrate that a transmission electron diffraction pattern (rings or spots) can be imaged in the 15° to 20° or more full-field view, from a thin (~ 100 nm or less) piece of Si, Al, Cu, or Ni.
* Demonstrate that a single spot within the pattern obtained above can be selected to create an image when synchronized with scanning of the incident electron beam. I.e., show that from the diffraction pattern seen by the detector, one diffracted spot can be selectively chosen as the one that will form the dark-field image upon synchronization with the scanning incident beam.
* Demonstrate collection of any transmission signal with the new detector design and how it can be used to form an image corresponding to the scanned specimen area.
* Demonstrate collection of a dark-field image created using one single diffraction spot obtained using the new detector design. I.e., there must be enough current in one diffraction spot to generate sufficient detector signal to form image contrast.
* Deliver prototype detector to NIST.

NIST staff is available for consultation, discussion, trial experiments to the extent necessary for clarification and to foster progress.

**9.02.03.63-R Electronics System for Microscale Thermogravimetric Nanoparticle Analysis**

As the market for high-purity and well-characterized nanoparticles grows, manufacturers need new cost-effective methods for characterizing materials in small quantities. Crystal microbalances (CMs) have promise for characterizing carbon nanotubes and other nanoparticles in a similar manner to but with significant reductions in sample size compared to techniques like traditional thermogravimetric analysis (TGA). The resonant frequencies of CMs are highly sensitive to mass deposited on the surface of the crystal and measurements of these frequencies can be used to determine mass changes on the order of picograms at ambient temperatures in laboratory environments. Researchers at NIST have demonstrated the feasibility of using heated CMs for microscale thermogravimetric analysis (µ-TGA) of nanoparticle samples in manufacturing settings, with resolutions that greatly surpass that of conventional thermogravimetric analysis.[1] While µ-TGA measurement systems developed at NIST [1-3] have been effective for demonstrating measurement methods on samples such as nanoparticles and polymers in the laboratory, there is a need for the development of a compact electronic system with greater sensitivity, speed, operational simplicity, and compatibility with manufacturing environments. The specific goal of this proposed SBIR project is to develop a compact electronic system and associated software for simultaneous measurement of resonant RF frequencies of an acoustic resonator during heating to elevated temperatures, while simultaneous monitoring temperature from a standard thermocouple. These electronics and software will serve as critical components for implementation of the first commercial µ-TGA system for industrial product analysis of nanoparticles.

Temperature-ramped µ-TGA studies at NIST have demonstrated the basic measurement approach and exceeded specifications of the most sensitive commercial TGA systems up to approximately 450 °C. However, the full potential of the approach, with respect to resolution, has not yet been realized, partly because of limitations on the speed and coordination of measurements of frequency and temperature.

In this SBIR subtopic, NIST is interested in pursuing the development of new hardware and software that, through enhancements in speed and data coordination, provides higher resolution and lower systematic errors in measurements of frequency and temperature than current experimental systems at NIST and achieves these features in manner that is more user friendly and cost-effective for product monitoring in industrial environments. Central challenges in this pursuit are associated with the substantial temperature dependence of the resonant crystals and the presence of interfering resonant peaks that pass through the frequency range of the mode of interest at particular temperature. Options for an electronics system that can both excite and monitor the resonator, while dealing with spurious modes, may include swept-frequency, tone-burst or self-locking oscillator approaches.

The electronics system must be able to monitor heating rates from 1 °C/min to 10 °C/min with a temperature reading at least every 1 °C up to 700 °C to be competitive with commercial TGA instrumentation. The standard deviation in temperature measurements must be on the order of 0.01 °C. Standard deviations and systematic errors in the frequency measurements must be limited to 5 Hz, and measurement intervals must be no greater than 1 °C. Temperature and frequency measurements will also need to be performed within 2 s of one another, with the relative times of the determined to within 0.1 s.

Phase I Activities:

* Develop an electronics approach which can detect acoustic resonator signals from crystal-based resonator systems at the sensitivity levels specified in the project goals.
* Provide a proof of concept measurement with NIST-provided samples to validate measurement approach.

Phase I Deliverables:

* A report that describes, in detail, their approach to acoustic resonator monitoring, including calculations and discussion on how the electronics approach will meet specifications on frequency resolutions, noise and drift.
* The awardee must travel to NIST in Boulder, CO to meet with project leads to discuss their approach, conduct preliminary measurements and give a short presentation on the highlights from the report. Preliminary measurements, to be performed on NIST-provided samples, must demonstrate:
* A 5 Hz standard deviation in measurements of the frequency of a thickness-shear mode near 15 mHz during heating at a rate of 5 °C/min with frequency measurements acquired at 1 °C temperature intervals.
* A 5 Hz systematic error in frequency measurement associated with finite dwell time (if swept-frequency measurements are pursued).
* A capability to track the frequency of a specified thickness-shear mode when resonant peaks of other modes pass through the frequency range of the specified mode during heating or cooling.

Phase II Activities:

* Design and build an electronic instrument that enables resonant acoustic frequencies of a crystal resonators to be measured, according to the specifications listed for Phase I. Provide a software interface compatible with Windows 7 computers where data is displayed in real time during testing and can be exported as text files for further analysis.
* Travel to NIST Boulder for delivery of instrument, as well as providing proof of concept measurements with NIST-provided samples.

Phase II Deliverables:

* Deliver a Phase II electronics system to NIST. Electronics system must:
	+ Be transportable. The design for the overall dimensions of the instrument should be on the order of a shoe box.
	+ Meet specifications for sensitivity and resolution as Project Goals and Phase I sections.
	+ Incorporate automatic triggering of both frequency and temperature readings. The user should be able to tailor the data collection rate of these measurements through the software.
* Provide a software interface for NIST scientists to use during testing and for exporting data for analysis.
	+ Software must be written in a common programming language, such as C++ or Basic, and not require incorporation in a higher-level proprietary programming system. All source code must be provided to NIST.
	+ Software should coordinate the recording of temperature measurements with measurements of frequency with a relative uncertainty of 0.1 s.
	+ Real time plots of temperature versus frequency should be plotted as experiments are running.
	+ Start/stop buttons, export data, and other convenient buttons should be integrated into the system.
* Installation and proof of concepts experiments should be done at NIST-Boulder. The awardee shall travel to NIST with the prototype instrument. Installation of the instrument, including coupling to NIST computers, resonators, and temperature systems will be done on site by the awardee. Training on the software interface should be provided.
	+ After installation, the awardee will conduct proof of concept experiments as described in Phase I with the addition of temperature measurements and the software package.
* Awardee will provide full electronic circuit diagrams, source code for software, a report on the final instrument design and operation, and a user’s guide for the instrument to NIST.

NIST scientists would be willing to work collaboratively with awardees in the development of an electronics monitoring system. NIST is willing to provide samples that would enable the awardee to test measurement systems prior to set-up meetings with NIST.

References:

[1] E. Mansfield, A. Kar, S. Hooker. “Application of Quartz Crystal Microbalances at Elevated Temperatures as an Alternative to TGA” Anal. Chem., 82 (24), 9977-9982, 2010.

[2] W. Johnson, E. Mansfield “Thermogravimetric analysis with a heated quartz crystal microbalance” *Frequency Control Symposium (FCS), 2012* *IEEE International,* 1-5, 2012.

[3] E. Mansfield, T. Quinn “Microscale thermogravimetric analysis for determining nanoparticle purity and surface coverage” SPIE Newsroom, 2011, doi: 10.1117/2.1201102.003528.

**9.02.04.68-TT Flowing Water Optical Power Meter for Laser Measurements**

Laser-based materials processing has become a commonplace manufacturing technique in a wide range of industries—from industrial cutting and welding in the manufacture of automobiles and airplanes to drilling tiny holes in consumer electronics. However, accurate power meters for these high-power lasers are not generally available—“accurate” meaning traceable to NIST standards and, in turn, to the SI.

NIST has been researching technologies and techniques for the design of such power meters. Our interest has been in the construction of reference standards that operates on the principle of electrical substitution (using the equivalence of heading a receiver to the same temperature both optically and electrically, with the electrical power being well-measured). We built a 100 kW standard in the 1970s, a 10 kW standard in 2011, and a 100 kW system in 2012. However, access to these standards is limited to the Department of Defense and its contractors. Furthermore, each is one-of-a-kind. The designs, though technically excellent, can be improved upon further. We envision an instrument that would be cheaper, easier to build, and easier to use. What is needed is a version of these power meters that can be produced commercially, at reasonable cost, for industrial, private sector, and other government applications.

Through this SBIR subtopic, we seek a partner to which we could transfer our knowledge and expertise, and who would, in turn, engineer and market a commercially viable 25 kW laser power meter.

The goal of the project is to design and build a flowing water optical power meter (FWOPM) that may be used to measure the real-time, average power of cw (continuous wave) lasers operating in the range of 500 W to 25 kW, with an accuracy of 1 % (*k*=2, or “2 sigma”) or better. It must be suitable for lasers operating at wavelengths of 1 μm and 10 μm.

NIST has developed several technologies that would be useful (if not essential) in such a design, and Offerors are encouraged to make use of them. We seek a small business with engineering and manufacturing resources to establish a commercially viable and ‘user friendly’ design based on our previous research, and to build and market the system. The NIST design documentation includes mechanical drawings, parts lists, electrical and plumbing schematics, etc., and while a URL is not available at press time, interested Offerors should inquire using the mechanism described elsewhere in this announcement. For additional information please see the NIST laser radiometry website <http://www.nist.gov/pml/div686/sources_detectors/laser.cfm> and the press release at <http://www.nist.gov/pml/div686/laser_power_meter.cfm>.

The FWOPM consists of three subsystems: Optical, Mechanical, and Electrical. The Optical subsystem consists substantially of a NIST-designed optical receiver, mirror, and a means to convert the laser radiation to heat. The Mechanical subsystem includes rotating machinery, plumbing, and portable racks for associated equipment. The Electrical subsystem includes a precision heater for substitution with the optical head, and electronic equipment for measuring fundamental electrical properties (current, voltage, resistance). NIST has written software to control various aspects of the FWOPM operation. We expect the final design to be compatible with our software (available to the awardee).

The FWOPM is intended be used at facilities where their large laser systems are not portable. Therefore the FWOPM must be designed to be portable itself. It must be transportable by regular commercial shippers, with the electrical, mechanical, and plumbing systems being contained in rack-mount shipping containers.

Phase I Activities:

* Construct optical receiver.
* Prepare coating material for the receiver.
* Specify and purchase mirror materials for optical receiver.
* Design and specify 25 kW electrical-substitution heater.

Phase I Deliverables:

* Coated optical receiver.
* Mirror subassemblies.
* 25 kW electrical-substitution heater.
* All documentation of Phase I designs and developments must be provided at the conclusion of Phase I.

Phase II Activities:

* Assemble physical structure relating subsystems. The physical structure may be thought of as a “skeleton” for electrical and mechanical subsystems that will be completed with “off-the-shelf” (pump, flow meter, water reservoir, heater electronics, etc.) components separately and independently.
* Complete the skeleton with pump, flow meter, water reservoir, and heater electronics.
* Provide optical components for mirror assembly.
* Coat optical receiver cavity.
* Assemble optical receiver cavity.
* Integrate optical receiver with other subsystems (mechanical, electrical, fluid)

Phase II Deliverables:

* Electrical and electronics components (rack mounted).
* Hydraulic and fluid flow systems (rack mounted).
* Fluid reservoir.
* Complete system for testing and comparison with NIST calibration services for 1.5 kW (1.06 µm) laser measurement.
* All documentation and a service manual.

We expect to work collaboratively and provide existing information (e.g., CAD drawings of existing hardware). We expect to provide limited testing (laser power measurements up to 1.5 kW). We expect to provide expertise in coating preparation.

References:

1. J.H. Lehman, et al., “Core-shell composite of SiCN and multiwalled carbon nanotubes from toluene dispersion,” J. Mater. Sci. (2010) 45:4251–4254.
2. M. Dowell, et al., “Comparison of Absolute Measurements of Laser Power Using Next-Generation NIST High-Power Radiometer and Air Force High-Power Calorimeter,” 2011 Solid State and Diode Laser Technology Review, 6–9 June 2011, Santa Fe, NM.
3. M. Dowell, et al., “Progress Towards an Absolute Reference for 100 kW Laser Power Measurements,” Third Annual Advanced High-Power Lasers Meeting, 11–14 June 2012, Broomfield, CO.

**9.02.05.68-R High Temperature Thermocouple and Radiation Thermometer Vacuum Furnace**

Temperature is the most widely measured parameter for a large range of manufacturing processes. Refractory materials processing, aerospace propulsion systems, and nuclear fuel systems all rely on special-alloy thermocouples for their high-temperature measurements [1]. This is generally limited to the use of platinum-rhodium (type B) thermocouples in air up to 1750 °C, and tungsten-rhenium (types C, D, and A) thermocouples in inert atmospheres up to 2350 °C [2-4]. These thermocouples are standardized using reference functions formulated in the 1960s based on the materials and processes available at that time.

There are significant problems with the tungsten-rhenium thermocouple reference functions and with the quality of the component metals. More than 50 % of the type C material and about 30 % of type D material received for calibration by NIST since 1990 exhibit deviations which are outside of the 1 % tolerance band established by ASTM standards. Manufacturers have coped with these uncertainties by periodically sending samples from thermocouple wire lots to NIST for certification / calibration. These calibrations have been performed by comparison to NIST-maintained reference wire for each basic thermocouple type; the measurement traceability is based on data that are 25 to 45 years old. The NIST-calibrated type D reference wire is now more than 2/3 exhausted, and NIST no longer has any capability to certify new tungsten-rhenium reference wire directly to the International Temperature Scale of 1990 (ITS-90).

While the basic metrology underlying the calibration of W-Re alloy thermocouple temperature readings using optical pyrometry in a high-temperature vacuum furnace is understood [5], there are significant engineering challenges involved with any state-of-the-art implementation. There are currently no commercial vacuum furnace systems which satisfy the requirements to allow the simultaneous measurements of the W-Re thermocouple output voltage and the optical pyrometry measured temperature. In addition, there are a variety of technical problems that make the necessary customization of existing designs impractical. Rather, an integrated solution is needed which has all the engineering constraints built into the design from the ground up.

The goal of the project is to produce an integrated high-temperature vacuum furnace system suitable for the direct comparison of high-temperature thermocouple readings with pyrometers measured temperatures in the range 900 °C to 2300 °C for the purposes of ITS-90 traceability and calibration of new lots of thermocouple alloys.

Phase I Activities:

* Establish the optimized cost/performance-effective technologies which meet the requirements.
* Design a complete integrated vacuum furnace system based on these technology solutions.

Phase I Deliverables:

* A set of detailed plans for construction of the vacuum furnace system.
* A bill of materials for completion of the system construction.

Phase II Activities:

* Construction of the design.
* Integration and testing of all system components.

Phase II Deliverables:

* An integrated vacuum furnace system conforming to the design specifications, delivered and installed.

The Temperature and Humidity Group has maintained a capability in high-temperature thermocouple calibration and expertise in furnace design for nearly 50 years. The Optical Radiation Group has the necessary expertise in radiation thermometry and modern solid-state detector technology. Through collaboration and consultations, we intend to address all the technical issues surrounding this project in working with the awardee.

References:

1. Anderson, T. M. and Bliss, P., “Tungsten-Rhenium Thermocouples Summary Report”, in *Temperature, Its Measurement and Control in Science and Industry*, Vol. 4, H. Plumb, Ed., Instrument Society of America, Pittsburgh, 1735-1746, (1972).
2. ASTM International, “Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples”, E230/E230M-11e1, West Conshohoken, PA, 2011.
3. ASTM International, “Standard Guide for Temperature-Electromotive Force (emf) Tables for Non-Letter Designated Thermocouple Combinations”, E1751/E1751M-09e1, West Conshohoken, PA, 2009.
4. International Electrotechnical Commission, “Thermocouples- Part 1, EMF specifications and tolerances”, IEC 60584-1, Ed. 3.0, Geneva, 2012.

5. ASTM International, “Standard Test Method for Calibration of Refractory Metal Thermocouples Using a Radiation Thermometer”, E452-02, West Conshohoken, PA, 2007.

**9.02.06.63-R Highly Multiplexed Spectroscopic Ellipsometer for In-line Process Control**

The development of novel, functional inks is leading to a revolution in low thermal budget, low cost roll-to-roll manufacturing of increasingly sophisticated technologies including flexible electronic devices and printed organic photovoltaic devices. There is a growing need for high-speed, precision measurements for in-line process monitoring of ink deposition in roll-to-roll systems. Spectroscopic ellipsometry is a powerful optical technique, well established for off-line characterization of complex, multilayer systems. However, the application to in-line measurements is hampered by the need for higher speeds and the use of transparent plastic substrates, which are commonly used in printed electronic devices. These substrates create measurement challenges due to variable optical anisotropy and the presence of interfering reflections from the backside of the substrate film. NIST is engaged in significant research into measurements to improve roll-to-roll manufacturing process monitoring. It seeks the development of novel, high speed, highly multiplexed, spectroscopic ellipsometers that address the challenges of roll-to-roll process monitoring on transparent substrates.

Spectroscopic ellipsometry has emerged as a very powerful tool for off-line characterization and quality control of complex thin film structures.[1] The most reliable analysis requires maximizing diversity in the data, typically by acquiring data at multiple angles of incidence. In the case that film components have in-plane anisotropy, data collection at multiple azimuthal angles is also required. In favorable cases, sub nm precision in complex film stacks can be achieved. However, the current generation of instruments is multiplexed only along the wavelength axis. Accordingly, acquisition of sufficiently diverse data for robust analysis is too slow for rapid in-line process monitoring in roll-to-roll manufacturing.

This project seeks innovative ellipsometer instrument designs to allow robust (highly diverse) data to be acquired in real-time. Recent advances in computational power and imaging polarimetry [2] based on passive (Stokes meter) components [3,4] suggest that highly-multiplexed ellipsometric systems can be achieved. A possible solution would leverage advances in hyperspectral polarametric imaging detectors that use 2D liquid crystal modulators as polarization state generators and high numerical aperture optics. This scheme could enable a multi-dimensional spectroscopic ellipsometer capable of acquiring full ellipsometric spectra at multiple angles of incidence and multiple azimuthal orientations in less than 0.1 sec. Use of high numerical apertures can limit the depth of focus to achieve critical distinction against the backside of transparent substrates.

Phase I Activities:

Instrument design of a highly multiplexed, spectroscopic ellipsometer capable of recording sufficient data in no more than 0.1 sec to completely characterize complex (4 layer) film stacks on transparent plastic substrates. Design must, at a minimum support:

* recording a spectrum with a minimum of 128 points over a 300 to 800 nm spectral range.
* a minimum of 3 angles of incidence.
* a minimum of three azimuthal angles.
* spectrum must contain at a minimum the 3 elements (one diagonal, two off diagonal) of the normalized Jones matrix. Measurement of a larger subset of the full Muller matrix is to be preferred.
* Design must intrinsically discriminate between front and rear reflections of 250 micrometer thick films.

Phase I Deliverables:

Report containing optical design and proof-of-principle measurements.

Phase II Activities:

Fabrication of highly multiplexed, spectroscopic ellipsometer and control system based on design of Phase I.

Phase II Deliverables:

* Delivery to NIST of a fully functional prototype, highly multiplexed, spectroscopic ellipsometer capable of: recording a spectrum with a minimum of 128 points over a 300 to 800 nm spectral range.
* a minimum of 3 angles of incidence.
* a minimum of three azimuthal angles.
* spectrum must contain at a minimum the 3 elements (one diagonal, two off diagonal) of the normalized Jones matrix. Measurement of a larger subset of the full Muller matrix is to be preferred.
* The minimum of 9 spectra (3 AOI, 3 azimuth) must be acquired in no more than 0.1 sec.
* The prototype must include an analysis capability of either real-time (<0.1 sec) library recognition or real-time ‘fitting’ to a 5 phase (substrate, 4 layers, ambient) model based on known dielectric functions.
* The design must intrinsically discriminate against artifacts from anisotropic, transparent substrates as demonstrated by the ability to measure a 35 nm Poly(3,4- ethylenedioxythiophene) poly(styrenesulfonate) film on a 250 micrometer polyimide substrate.

During Phase I and II NIST staff will be available for consultation and discussion of design.

References:

1. Hiroyuki Fujiwara, “Spectroscopic Ellipsometry Principles and Applications” John Wiley and Sons, Ltd 2007.

2. John R. Schott, “Fundamentals of Polarimetric Remote Sensing” SPIE Tutorial Text Vol TT81, 2009.

3. J. Larry Pezzaniti, et al. “Four camera complete Stokes imaging polarimeter” SPIE Proceedings Vol 6972, 2008.

4. Neal Brock, et al. “A pixilated micropolarizer-based camera for instantaneous interferometric measurements” SPIE Proceedings Vol 8160, 2011.

**9.02.07.73-R Life Cycle Impact Analysis Tool for Sustainable Manufacturing**

This SBIR subtopic seeks the development of a tool that uses identified data and defined analysis and synthesis procedures to support interoperability among design engineering tools (such as Computer aided Design-CAD, Product Data Management-PDM, Product Lifecycle Management-PLM), engineering and manufacturing analysis tools (such as Computer Aided Engineering-CAE, Computer Aided Manufacturing-CAM) and Life Cycle Assessment (LCA) tools. Such a tool should:

* Support a well-defined information model for developing Product Category Rules (PCRs).
* Enable closed-loop information exchange between engineering authoring tools and (LCA) tools, facilitated Environmental Product Declarations (EPDs) and PCRs.
* Provide a unified product model that includes energy and material information to enable a feed-forward and feedback of information among the CAD/PDM/PLM and LCA tools.
* Enable an information-modeling framework necessary to address the interworking of various product standards for sustainability, where applicable (1404x, 1406x, Green House Gas (GHG) protocol, Global Reporting Initiative (GRI)).

In order to do a “what-if” analysis and synthesis for sustainability considerations in the early design phase it is critical to integrate environmental aspects into product design and development, product lifecycle management and total lifecycle analysis. Currently the information flow between engineering authoring tools (CAD/CAE/CAM/PDM/PLM) and LCA tools related to sustainability (energy, material, and environment) is not well defined, and the efforts are often duplicated. Moreover, sustainability requirements are not well captured during the early design stage for life cycle impact analysis. There is a growing demand to compare similar products based on their life cycle impacts. However, there are many technical challenges in ensuring that such comparisons are valid. To do so, there is a need for methodological consistency at the product category rules (PCR) level. PCRs1 provide a mechanism for agreeing on specific rules in relationship to individual product categories. PCRs are established under ISO 14025:2006 with the aim of improving comparability. The Global Environmental Declarations Network (GEDnet) is an effort to develop a repository for PCRs [1]. The sustainability performance of products differs significantly according to the product categories (where a product category is defined as a group of products that can fulfill equivalent user needs). Hence, it is critical to select a set of appropriate indicators and calculation rules based on product categories.

To address the information management challenges related to the incorporation of PCRs, U.S. companies need an integrated systems approach. A systems approach is necessary for designers and engineers to compute, track, and compose selected sustainability metrics. A number of metrics and associated computational methods have been suggested. The most critical of these metrics are associated with energy efficiency and material efficiency. However, there exists no measurement science-based methodology to enable analysis and synthesis (allocation) of the energy and material footprints at the factory level for gate-to-gate life cycle impacts. This is one of the main objectives of NIST Sustainable Manufacturing Program [2]. To develop such a methodology for manufactured products that would permit design engineers to try out different material and manufacturing approaches for products, a good understanding of EPD, as they build their designs, is critical.

Understanding the trade-offs of product design choices requires a well-defined Environmental Product Declaration (EPD), backed by LCA studies and based on appropriate PCRs. It is also required to clearly define the definition of relationships between the EPDs/PCRs, the design models, and the LCI data. The definition of these relationships will enable the co-generation of an EPD as the design evolves and thus enable a feed-forward and feedback of information flow among the CAD/CAE/PDM/PLM and LCA tools (round-trip engineering). To formally define these relationships, a PCRML (PCR schema based on eXtensible Markup Language-XML) could be developed to benefit the industry. In addition to this, product sustainability impact analysis requires data from the supplier network and it necessitates an advanced definition of product concept and modeling for data aggregation and decision support.

The awardee will work with NIST staff members involved in sustainable manufacturing R&D to develop requirements for developing a generic unified model of product structure model that includes information required for computing sustainability that goes beyond the traditional bill-of-materials (BOM) to the notion of Sustainable BOM (SBOM). The SBOM includes bill-of-substances (BOS), bill-of-carbon (BOC) [3] and methodologies for Life Cycle Analysis and Synthesis as the foundation for design for sustainability (DFS) [4]. This will allow trade-off analysis of various design choices for manufacturability across the supply network.

A successful Phase I submitter would deliver the following to NIST:

* Requirement analysis and data exchange schema for the following: i) information models for materials and energy for various applications (selection [5], tracking, efficiency, and compliance), ii) integration of the materials and energy information to traditional BOMs to develop BOS, iii) incorporating additional semantics to product model (ontologies, uncertainty model, data quality) to enable decision making with respect to sustainability requirements.
* Proof of concept case study to demonstrate the integration of design tools with life cycle analysis tools for design optimization for sustainability.
* Requirement analysis to maximize the application of available standards such as STEP (ISO 10303-xxx), ISO 14000 and relevant standards and regulations.

A successful Phase II submitter would deliver the following to NIST:

* Tools and methods for incorporating sustainability measures as design-time criteria, with an initial focus on energy and material efficiency across the production networks.
* Necessary standards based application-programming interfaces (APIs) for integration among design tools, engineering analysis tools, and LCA tools.
* A service oriented architecture based solution for such integration.
* Open standards for interfacing design tools, engineering analysis tools, and LCA tools.
* A framework that includes a generic model of product structure and methodologies for Life Cycle Analysis and Synthesis as the foundation for design for sustainability (DFS), to do trade-off analysis of various design choices.

NIST will consult and provide inputs and work closely with the awardee to assess progress and performance.

References:

[1] Global Type III Environmental Product Declarations Network-[GEDNet](http://gednet.org/) Repository.

[2] Sustainable Manufacturing Program - <http://www.nist.gov/el/msid/lifecycle/sustainable_mfg.cfm>.

[3] <http://h30507.www3.hp.com/t5/Supply-Chain-Management-Blog/BOS-BOC-new-acronyms-to-get-used-to/ba-p/36514>.

[4] Design for Sustainability - <http://www.d4s-de.org/>.

[5] Tools such as Granta MI - <http://www.grantadesign.com/products/mi/system.htm>.

1 These are the detailed instructions on how to perform the LCA for product declarations - A Roadmap to Environmental Product Declarations in the United States, [www.lcacenter.org/pdf/Roadmap-to-EPDs-in-the-USA.pdf](http://www.lcacenter.org/pdf/Roadmap-to-EPDs-in-the-USA.pdf)

**9.02.08.77-R Model-based Smart Manufacturing of Composite Materials**

When fiber materials such as glass, carbon, boron, or silicon carbide, are bonded with polymeric (e.g., epoxies, resins), mineral, or metallic (e.g., aluminum, titanium) matrix materials, a composite material with properties different from either the fiber or the matrix is created. During the last 50 years, advances in the manufacturing of composite materials have been so successful that today a multi-billion-dollar industry exists not only in the United States, but also in many other countries, with a huge array of products ranging from aircrafts, marine transports, wind turbines, to sports and recreational fixtures.

As described by Milton [1], Gay and Hoa [2], and Tsai [3], all such products are designed and manufactured using a temperature-and-pressure-based molding and forming process. In general, a product may have many parts, some of which may be made of composite materials. A typical process in the manufacture of a composite material product is the nondestructive inspection (NDI) of a part before it reaches the assembly floor. For example, a sound NDI procedure should yield quantitative information on the detection, location, and sizing of micro-cracks, various types of porosity, or specific geometry of de-bonding. In spite of the codification of the NDI reliability assessment procedure [4] and the reporting of significant advances in NDI methods [5-8] such as ultrasonics, x-ray, Rayleigh surface wave, terahertz radiation (T-ray), acoustic emission, and imaging (AFM and UFM) techniques, Rummel [9] stated in a recent survey article on NDI reliability that “*although NDI has a long history of use in quality assurance, it is behind the maturity level of engineering design tools, and that mismatch continues to challenge potential benefits and use*.”

To address this shortcoming in NDI technology, it is a common practice among composite material manufacturers that an in-house committee of experts is convened to judge subjectively whether a part is acceptable after reviewing the NDI data of its “imperfections” or “damage.” Such practice ignores recent advances in fracture mechanics [10], finite element modeling (FEM) of stress analysis [11, 12], and stochastic modeling and simulation of failure tests of specimens and parts with known distribution of defects [13-17]. The development of a model-based, intelligence-enhanced, and easy-to-use simulation code to assist the NDI committees of composite material manufacturers in more quantitative and efficient decision making, appears to be timely, and is thus proposed here as a two-phase SBIR subtopic.

To assist a composites material manufacturer of strength-critical parts without going through a time-consuming and costly experimental proof test for quality assurance, three types of innovations are needed in developing a model-based manufacturing quality assurance tool tailored to the inspection process of a composite material part:

(1) To convert a sample of the nondestructive evaluation (NDE)-based imaging or measurement data on a bulk composite material specimen or part to a statistically- validated representation of the nondestructive inspected state with defects captured either as images or NDE signals-modeled data.

(2) To construct a nondestructive inspected defect-detected state characteristics database that should be broad enough to include as many known “damage” states of as-manufactured parts as possible.

(3) To convert the statistical representation of a typical “damage” state in the database to a finite element mesh that is amenable to a stochastic finite-element-method (FEM)-based simulation of two test scenarios: (a) an ultimate biaxial strength test of a specimen, and (b) a proof test of an as-manufactured part using the tools developed in the first two types of innovations and the experimentally-validated simulation results of test (a).

The development of a powerful manufacturing quality assurance tool such as the one proposed in this subtopic requires the combination of technical skills and leadership in a large number of scientific and engineering disciplines, rarely available in small and medium-sized companies. Once the tool is developed, its use will enable a large number of manufacturers to improve quality and save cost and time.

The model-based NDI technology described in this subtopic has its roots in the knowledge base known as the science of precision manufacturing. One of NIST’s key missions is to assist the nation’s manufacturers through research in uncertainty quantification (UQ). NIST is therefore interested in making available its UQ knowledge base to the nation’s manufacturers through the development of this tool. In addition, such tool, when widely used, may also lead to the development of standards in manufacturing, another key mission of NIST.

Project Goals:

1. To design and test the feasibility of a stage-1 code with Bayesian-based intelligence to convert a sample of nondestructive evaluation (NDE)-based measurement or imaging data on bulk composite laminate specimens to a collection of finite-element meshes, each with a well-defined distribution of “damages” of increasing severity.
2. To design and test the feasibility of a stage-2 code with stochastic finite-element model (FEM)-based simulation of the ultimate biaxial strength tests of a batch of composite laminate specimens of varying degrees of damage severity after undergoing the same time-temperature-pressure history of curing/molding process as the composite part being manufactured.
3. To design and test the feasibility of an experimental plan to validate the prediction of the stage-2 code.

To design and test the feasibility of a stage-3 code with stochastic finite element model (FEM)-based simulation of the proof test to failure of a full-scale as-manufactured composite part with NDE-based damage characteristics comparable to those in the specimen damage database.

Phase I Activities:

1. Design of a three-stage computer code for in-situ damage characterization and ultimate strength estimation of a batch of composite laminate specimens with capability to apply the specimen batch results to the estimation of the ultimate strength of a full-scale manufactured composite part for quality assurance.
2. Development of an example computer algorithm for the stage-1 code (from nondestructive evaluation (NDE)-based measurement or imaging data to damage characterization for a batch of composite specimens of varying degrees of severity).
3. Development of an example computer algorithm for the stage-2 code (stochastic finite element model (FEM)-based analysis of a batch of composite specimens with varying degrees of damage severity for estimating their ultimate biaxial strengths).
4. Development of an example computer algorithm for the stage-3 code (stochastic finite element model (FEM)-based analysis of a full-scale as-manufactured composite part with NDE-based damage characteristics comparable to those in the specimen damage database such that the ultimate strength proof test of the as-manufactured part can be simulated using the stage-1 and -2 codes to characterize the damage state of the part and the experimentally-validated simulation results of the biaxial strengths of the specimens via also the stage-3 code.
5. Preparation of Phase I final report.

Phase I Deliverables:

1. A design document of a three-stage code for assessing the ultimate strengths of a full-scale manufactured composite part using NDE data on the part and analysis results of a batch of composite laminate specimens of varying degrees of microstructural imperfections.

A feasibility study with an example computer algorithm for the stage-1 code (from NDE measurement or imaging data to damage characterization of a composite laminate specimen).

1. A feasibility study with an example computer algorithm for the stage-2 code (stochastic FEM-based simulation of the ultimate biaxial strength test of a single composite specimen with a typical distribution of microstructural damage and time-temperature-pressure curing/molding history).
2. A feasibility study with an example computer algorithm for the stage-3 code (stochastic FEM-based simulation of the proof test of a full-scale as-manufactured composite part with a specific time-temperature-pressure curing/molding history and a damage characteristics comparable to those in the specimen damage database).

A Phase I final report with a summary of results from previous deliverables.

Phase II Activities:

Using the results of the Phase I work and the lessons learned, revise the design of a three-stage computer code for in-situ damage characterization and ultimate strength estimation of a batch of composite laminate specimens with capability to apply the specimen batch results to the estimation of the ultimate strength of a full-scale manufactured composite part for quality assurance.

Contact and invite a potential user of the model-based NDI tool to collaborate for the purpose of validating the three-stage codes. Develop a design of experiment and a plan for implementing the testing as outlined in Phase II Activities 3, 4, 5 and 6.

Develop, test, and validate the stage-1 code on a batch of specimens and a *typical* full-scale as-manufactured part made of the same composite material and having the same time-temperature-pressure history of curing/molding process. Purpose of the stage-1 code is to convert nondestructive evaluation (NDE)-based measurement or imaging data to damage characterization for specimens of varying degrees of severity and for the *typical* part. The output of the stage-1 code must be a validated statistical representation of the damage state of a composite material specimen or the *typical* part, and a 3-dimensional finite element mesh of the specimen and the *typical* part that is amenable to FEM-based stress analysis of a given specimen or part geometry for arbitrary dynamic or quasi-static loadings.

Construct Database-1 of specimen damage states of increasing severity, which should be broad enough to include as many known damage configurations as possible. In particular, the Database-1 must include a cluster of states, within which the damage state of the *typical* part can be located. If not, repeat Phase II Activity 3 until Database-1 is broad enough to contain the damage state of the *typical* part chosen for the Phase II work.

Develop, test, and validate the stage-2 code on a batch of specimens with varying degrees of severity. Purpose of the stage-2 code is to conduct a stochastic finite element model (FEM)-based analysis of the specimens for estimating their ultimate biaxial strengths. Validate the predictions of the stage-2 code with experimental data. Revise and test the stage-2 code on specimens until the code is satisfactorily verified and validated. Construct Database-2 of the specimen ultimate biaxial strengths corresponding to each of the damage states listed in Database-1.

Using results of Phase II Activities 3, 4, and 5, develop, test, and validate the stage-3 code on the typical part. Purpose of the stage-3 code is to conduct a stochastic finite element model (FEM)-based analysis of a *typical* full-scale as-manufactured composite part with NDE-based damage characteristics comparable to those in the specimen damage database such that the ultimate strength proof test of the as-manufactured part can be simulated. Validate the predictions of the stage-3 code with experimental data. Revise and test the stage-3 code on the *typical* part until the code is satisfactorily verified and validated.

Prepare Phase II final report.

Phase II Deliverables:

1. A revised design document of a three-stage code for assessing the ultimate strengths of a full-scale manufactured composite part using NDI-based imaging or measurement data on the part and the experimentally-validated simulation results of a batch of composite laminate specimens made of the same material and having the same time-temperature-pressure-history of the curing/molding process as the part.
2. A written agreement with a potential user of the model-based NDI code for the Awardee to collaborate and validate the three-stage computer code with experimental data. Attach to the agreement a design of experiment and a plan for implementing the testing as outlined in Phase II Activities 3, 4, 5, and 6.
3. A working stage-1 code that has been tested and validated on a batch of specimens and a *typical* full-scale as-manufactured part made of the same composite material and having the same time-temperature-pressure history of curing/molding process. The output of the stage-1 code must be a validated statistical representation of the damage state of a composite material specimen or the *typical* part, and a 3-dimensional finite element mesh of the specimen and the *typical* part that is amenable to FEM-based stress analysis of a given specimen or part geometry for arbitrary dynamic or quasi-static loadings.

A working Database-1 of specimen damage states of increasing severity, which should be broad enough to include as many known damage configurations as possible. In particular, the Database-1 must include a cluster of states, within which the damage state of the *typical* part can be located. The Database-1 must be user-friendly in its search and retrieval capabilities.

A working stage-2 code that has been tested and validated on a batch of specimens with varying degrees of severity. Purpose of the stage-2 code is to conduct a stochastic finite element model (FEM)-based analysis of the specimens for estimating their ultimate biaxial strengths using the output of the stage-1 code. A validation report is attached to the stage-2 code after an iterative procedure where the model-based code is revised to obtain a reasonable agreement between the code prediction and the experimental data. A working Database-2 is also attached to the stage-2 code with a listing of the ultimate biaxial strengths of the specimens corresponding to each of the damage states listed in Database-1.

1. A working stage-3 code that has been tested and validated on the *typical* part. Purpose of the stage-3 code is to conduct a stochastic finite element model (FEM)-based analysis of a *typical* full-scale as-manufactured composite part with NDE-based damage characteristics comparable to those in the specimen damage database such that the ultimate strength proof test of the as-manufactured part can be simulated. A validation report is attached to the stage-3 code after an iterative procedure where the model-based code is revised to obtain a reasonable agreement between the code prediction and the experimental data. A simulated proof test report for the ultimate strength of the *typical* part is also attached to the stage-3 code.

A Phase II final report with a summary of results from previous deliverables.

NIST is available for consultation on clarification of the scope and goals of the project and for discussion on a review of preliminary results to see if they are within scope and are aligned with project goals.

References:

[1] Milton, G. W., 2002, *The Theory of Composites*. Cambridge University Press (2002).

[2] Gay, D., and Hoa, S. V., 2007, *Composite Materials: Design and Applications*, 2nd ed. CRC Press, Taylor and Francis Group, Boca Raton, FL 33487 (2007).

[3] Tsai, S. W., ed., 2008, *Strength and Life of Composites.* Published by the Composites Design Group, Department of Aeronautics and Astronautics, Stanford University, Stanford, CA 94305-4035, (2008).

[4] Department of Defense, 1999, *Nondestructive Evaluation System Reliability Assessment*, United States Department of Defense Handbook MIL-HDBK-1823, 30 April 1999.

[5] Welter, J. T., Sathish, S., Tandon, G. P., Schehl, N., Cherry, M., Nalladega, V., Lindgren, E. A., and Hall, R., 2012, “Thermo-elastic Nondestructive Evaluation of Fatigue Damage in PMR-15 Resin,” *Review of Progress in QNDE,* Vol. 31B, pp. 1088-1093. American Institute of Physics, Melville, NY (2012).

[6] Chiou, C. P., Margetan, F. J., Barnard, D. J., Hsu, D. K., Jensen, T., and Eisenmann, D., 2012, “Nondestructive Characterization of Ultra-high molecular-weight polyethylene (UHMWPE) Armor Materials,” *Review of Progress in QNDE,* Vol. 31B, pp. 1168-1175. American Institute of Physics, Melville, NY (2012).

[7] Walker, S. V., Kim, J. Y., Jacobs, L. J., and Qu, J., 2012, “Characterization of Fatigue Damage in A36 Steel Specimens using Nonlinear Rayleigh Surface Waves,” *Review of Progress in QNDE,* AIP Conf. Proc. 1430, Vol. 31B, pp. 1415-1421. American Institute of Physics, Melville, NY (2012).

[8] Yoon, D. J., and Han, B. H., 2012, “Effective AE Source Location of Damages in American Institute of Physics, Melville, NY (2012).

[9] Rummel, W. D., 2012, “Nondestructive Inspection Reliability – History, Status and Future Path,” *Proc. 18th World Conf. on Nondestructive Testing,* 16-20 April 2010, Durban, South Africa, (2012).

[10] Kanninen, M. F., and Popelar, C. H., 1985, *Advanced Fracture Mechanics.* Oxford University Press (1985).

[11] Zienkiewicz, O. C., and Taylor, R. L., 2000, *The Finite Element Method,* 5th ed., Vol. 1, The Basis. Butterworth-Heinemann (2000).

[12] Velichko, A., and Wilcox, P. D., 2011, “Efficient finite element modeling of elastodynamic scattering from near surface and surface breaking defects,” *Review of Progress in QNDE,* Vol. 30, pp. 59-66. American Institute of Physics, Melville, NY (2011).

[13] Fong, J. T., Marcal, P. V., Hedden, O. F., Chao, Y. J., and Lam, P. S., "A Web-based Uncertainty Plug-In (WUPI) for Fatigue Life Prediction Based on NDE Data and Fracture Mechanics Analysis," *Proc. ASME Pressure Vessels & Piping Conference*, July 26-30, 2009, Prague, TheCzech Republic*,* Paper No. PVP2009-77827. New York, NY: ASME, <http://www.asme.org/kb/proceedings>(2009).

[14] Fong, J. T., deWit, P., Marcal, P. V., Filliben, J. J., and Heckert, N. A., *"*A Design of Experiments Plug-In for Estimating Uncertainties in Finite Element Simulations,*" Proceedings of 2009 International SIMULIA Conference*, May 18-21, 2009, London, U.K., pp. 828-842. Providence, RI: SIMULIA-Dassault Systemes Simulia Corp. (2009).

[15] Shah, P. D., Melo, J. D. D., Cimini, C. A., and Fong, J. T**.,** "Composite Material Property Database Using Smooth Specimens to Generate Design Allowables with Uncertainty Estimation," *Proc. ASME Pressure Vessels & Piping Conference*, July 18-22, 2010, Bellevue, Washington,Paper No. PVP2010-26145. New York, NY: Amer. Soc. of Mech. Engineers, [http://www.asmeconferences.org/PVP2010](http://www.asmeconferences.org/PVP2010%20)(2010).

[16] Fong, J. T., “Composites Failure Criteria, Uncertainty Propagation, and Estimation of the A-basis and B-basis Design Allowables,” *Proc. 2012 JEC/Europe Composites Forum*, Paris, France, Mar. 27, 2012, *JEC Composites Magazine*, No. 71, March 2012, pp. 87-90. [www.JECcomposites.com](http://www.JECcomposites.com).

[17] Todd, M. D., Flynn, E. B., Wilcox, P. D., Drinkwater, B. W., Croxford, A. J., and Kessler, S., 2012, “Ultrasonic Wave-Based Defect Localization Using Probabilistic Modeling,” *Review of Progress in QNDE,* Vol. 31A, pp. 639-646. American Institute of Physics, Melville, NY (2012).

**9.02.09.63-TT Nanoparticle Separation: Magnetic Field Opposing a Buoyant Density Gradient**

*\* This subtopic requires that a license* [***application***](http://www.nist.gov/tpo/sbir/upload/NonExclusiveRoyaltyFreePatentLicenseSBIR.pdf) *be submitted in conjunction with the proposal. Be sure to include one, signed copy along with the proposal package.*

To separate high value carbon nanotubes and other “hard” nanoparticles with densities in the 1 to 1.75 gm/cm3 range and inducible magnetic moments a concept has been demonstrated that uses a static magnetic field generated by a room temperature permanent neodymium magnetic placed underneath an aqueous buoyant density gradient (glycerol, silicon oils, cesium chloride, etc). The nanoparticle is overlaid on the denser gradient layer in aqueous solutions using ionic or non-ionic detergents. For a particle with an inducible magnetic moment or particles that can be linked to magnetic nanoparticles, a downward force is generated by the attractive force of the magnetic field. With a closely matched opposing buoyant density force the nanoparticle is separated in an equilibration process by its inherent magnetic properties and buoyant density (proportional to size, shape, diameter, etc). In practice, subtle differences in the magnetic and buoyant density of nanoparticles can be reflected in their separation into layers in a buoyant density gradient to unique positions where opposing forces acting on the nanoparticle are matched. With non-ionic detergents, initial tests suggest separation of SWCNTs by chirality and radius is possible using this approach. Advantages of this separations approach are its simplicity, low cost and ease of scalability. As a production method, it has the potential to replace g-forces, which require high velocity, high capacity centrifuges, with magnetic forces to separate nanoparticles. Currently methods which rely on high velocity, high capacity centrifuges severely limit the production of size and chirality sorted SWCNTs. Without new approaches as sought here which aim to scale production of high quality SWCNTs, the potential of these nanoparticles in application areas ranging from microelectronics to clinical therapeutics will never be realized.

This initial goal of this project will be to reproduce the findings reported in Patent US8251225 B2 using processed ‘grit sheared’ SWCNTs and other isolated SWCNTs and the original cylindrical tube design (as shown in Patent US8251225 B2). The Offeror will be expected to explore the effectiveness of the method using various nanoparticle materials of various purity grades (of particular interest would be tests with high value chiral SWCNTs), different dispersing surfactants, and different methods to generate the aqueous buoyant density gradient (glycerol, silicon oils, cesium chloride, etc). The goal will be determine at what point in the multi-step purification process reported in Patent US8251225 B2 is the method best applied: as a pre-processing step, intermediate or final step.

The awardee will also be expected to test and optimize different approaches for nanoparticle harvesting after separation. Initial tests would involve reproducing and adapting for scalability the approach of freezing and slicing for recovery of particles after separation. Alternative approaches may also be explored.

The awardee will then be expected to adapt the hardware design (e.g. large surface area trays with minimal depth and modest magnetic fields) to allow scale-up of the process of nanoparticle separation using the magnetic force driven, buoyant density gradient method.

Phase I Activities:

* Reproduce the ‘magnetic-buoyant gradient density separation’ reported in Patent US8251225 B2 using processed ‘grit sheared’ SWCNTs and the original cylindrical tube design (as shown in Patent US8251225 B2).
* Explore the performance of different dispersing surfactants, and different methods to generate the aqueous buoyant density gradient (glycerol, silicon oils, cesium chloride, etc).

Explore the effectiveness of the ‘magnetic-buoyant gradient density separation’ method using other commercially available grades of SWCNTs materials of various purity grades (of particular interest would be tests with high value chiral SWCNTs).

Phase I Deliverable:

Report of the results of the three bulleted activities listed in Phase I.

Phase II Activities:

* Test and optimize a ‘best practices’ approaches for SWCNTs harvesting after separation. Initial tests would involve reproducing and adapting for scalability the approach of freezing and slicing for recovery of particles after separation. Implement design alternations or develop alternative approaches for harvesting as necessary.
* Adapt the hardware design (e.g. large surface area trays with minimal depth and modest magnetic fields) to allow scale-up (up to kilogram quantities) of the ‘magnetic-buoyant gradient density separation’ reported in Patent US8251225 B2 for nanoparticle separation using the magnetic force driven, buoyant density gradient method.

Explore the application of the ‘magnetic-buoyant gradient density separation’ reported in Patent US8251225 B2 using other magnetic nanoparticles or magnetic nanoparticle conjugates.

Phase II Deliverables:

Report of the results of the bulleted activities listed in Phase II.

* Deliver the design and prototype device that demonstrates a scaled up process (up to 1 kilogram) using magnetic and buoyant density forces.

Deliver a design for multiplexing the devices for pilot scale manufacturing with minimal space footprint and energy requirements.

During Phase I and II, NIST staff will be available for consultation and collaboration on experimental design and measurements.

Reference:

Harvesting of Processed Carbon Nanotubes, Patent US8251225 B2.

**9.02.10.63-TT Recirculating Temperature Wave Focusing Chromatography**

*\* This subtopic requires that a license* [***application***](http://www.nist.gov/tpo/sbir/upload/NonExclusiveRoyaltyFreePatentLicenseSBIR.pdf) *be submitted in conjunction with the proposal. Be sure to include one, signed copy along with the proposal package.*

Methods to improve the sensitivity and resolution of chromatographic techniques are broadly applicable across all aspects of chemical analysis. With most chromatographic techniques there is a trade-off between sensitivity and resolution. For example, if a larger amount of sample is injected, the sensitivity is typically improved but the resolution is degraded. With some chromatographic methods, such as gas chromatography, methods have been developed for the injection of a large volume of sample in such a way that the analytes are preconcentrated at the beginning of the column (or in another short column), and then released in a sharp plug to elute along the column. In this way, the sensitivity of a method can often be improved without significant degradation of the resolution. However, with existing large volume injection methods, the preconcentration step has only limited selectivity. Consequently, they are of little value in improving the sensitivity with samples containing high concentrations of interferent species that are similar to the chemical species targeted for measurement. In these cases, preconcentration of a large volume injection leads to overloading of the column with the high concentration interferents.

The invention that is the subject of this SBIR subtopic is a device that allows for (among other advantages) large volume injections (or even continuous sample injections) but with the ability to selectively preconcentrate analytes using the high selectivity of the chromatography column itself. Successful implementation of this invention within a commercially available chromatographic platform would result in qualitatively new capabilities for high sensitivity and high resolution chemical analysis. The invention is described in detail in US patent 8,226,825.

Development and demonstration of a prototype instrument for recirculating temperature wave chromatography. The proof-of-concept experiments described in the patent specification were performed with gas chromatography. Gas chromatography would be an acceptable mode for demonstration under this project as well, and could benefit from recently developed technologies for rapidly heating and cooling gas chromatography columns. Proposals for demonstration with other modes of chromatography (liquid chromatography, for example) will also be considered however. It is also desired that the instrument be compatible with existing commercially available chromatography instruments and that it be capable of operating with continuous or near-continuous sample injection as well as performing the operations described in the proof-of-concept data in US patent 8,226,825 (multiple repeated injections, peak cutting, on-the-fly optimization of temperature wave).

Phase I Activities:

Development of a single column apparatus capable of supporting a temperature wave (gradient in both time and space) appropriate for use with recirculating temperature wave chromatographic focusing.

Phase I Deliverable:

Report containing apparatus design and proof-of-concept data (temperature vs. time data and chromatographic data demonstrating analyte focusing.

Phase II Activities:

Development and construction of a recirculating temperature wave focusing chromatography instrument.

Phase II Deliverables:

Delivery to NIST of prototype instrument and control software. Capabilities to include continuous or near-continuous sample injection, multiple repeated injections, peak cutting, and on-the-fly optimization of temperature wave. Instrument also to include non-destructive detector for monitoring analyte focusing during recirculation.

NIST staff are available for consultation, discussion, trial experiments to the extent necessary for clarification and to foster progress

Reference:

US patent no. 8,226,825, D.J. Ross., Recirculating temperature wave focusing chromatography.

**9.02.11.68-R Three-Dimensional Test Materials for Solid Supports**

Nanotechnology offers vast potential for future manufacturing. Already, the properties of nanoparticles and other nanomaterials are being investigated for a wide range of advanced applications. Three-dimensional (3D) solid supports with complex nanoscale pore structure are an example of a materials system with a long history of application in chemical processing, compared to the field of nanotechnology. Solid-phase supports refer here to packable materials with extensive pore networks throughout its bulk. The average pore diameter of the network is controlled during manufacturing. In addition, chemically active sites are present throughout the pore structure. Such sites can be selectively modified to reversibly bind chemical reagents or act as sites of antigen-antibody interactions. Physical confinement of chemical reactions at the nanoscale allows high yields and selectivity of the final reaction products. For this reason, solid supports now have a well-established role in the synthesis, separation, and purification of organic compounds and biomolecules, particularly high-value-added drug concepts under investigation by the pharmaceutical industry. The potential of solid-phase supports to further impact advanced manufacturing processes can be enhanced by optimizing several factors: rational design of the macro- and nanoscale properties of the support structure itself; predictive control of the distribution of reactive or binding sites throughout the 3D network; and optimization metrics that allow such processes to scale up smoothly from R&D to manufacturing quantities. Purity and yield of chemically based processes are improved relative to bioreactor approaches for manufacturing applications where there are strict regulatory demands on quality assurance. For high-value-added products this is potentially of great financial interest. (For example, the market for oligonucleotides—which is just now emerging from R&D and clinical trials to marketable drugs—is presently in excess of $100 M.)

NIST has a strategic thrust in the area of 3D nanomicroscopy and nanometrology. By promoting accurate measurement methods, standards, and improved predictive models of active 3D network materials, this proposal seeks to encourage industry to develop more innovative uses of solid supports in advanced manufacturing. Because such materials are available in large quantities and have a well-established commercial presence, they provide a ready source of material available for testing by NIST. The improved microscopy and modeling techniques generated in the course of evaluating such materials will lead to immediate benefits for chemical and biochemical manufacturers that rely on solid supports for efficient processing. Since these benefits accrue at the first link in the supply chain, the impact can be considerable.

The overall goal of this project is to develop a better understanding and industrial use of solid support materials. In order to facilitate this goal, NIST wishes to develop a series of materials for its own in-house testing, whereby optimization of physical parameters, such as network pore size and coating material, will lead to improved prediction and measurement processes throughput, pore loading, and other critical performance metrics of modifiable 3D nanoscale solid supports. More specifically, we propose to use the series of test materials developed by the awardee under this proposal to derive improved porosity and dynamic binding capacity estimates and thus remove a critical bottleneck in manufacturing applications of these materials. By providing a validated basis for the rational design and optimization of scalable, dimensionally stable nanoporous systems, these results are expected to be useful for solid support suppliers, instrument vendors, and contract manufacturers of high-value added chemicals, especially in pharmaceutical R&D and manufacturing.

Phase I Activities:

The awardee will propose a material system and manufacturing process consisting of the following components (during Phase I these components will be considered as parallel development steps):

1. A dimensionally stable solid support (i.e., its pore size and structure do not depend on solvent effects) with variable pore sizes that span the industrially relevant 50 nm to 300 nm pore diameter range. The pore size is to correspond to a statistical diameter as determined by industrially recognized porosity measurements.

A series of reference thin films capable of possessing a stated mean density of reactive sites. The thin film coating process must be ultimately compatible with conformable adhesion to the solid support. Reactive sites will be tagged by the awardee with a suitable particle or molecule (e.g., gold nanoparticle, protein, or fluorophore) in consultation by and agreement with the NIST technical contact such that the site density and uniformity of coverage of the film can be quantified by methods available to both parties.

Phase I Deliverables:

The awardee will provide and prepare multi-gram quantities of a series of at least five solid support materials with pore sizes that include the industrially relevant 50 nm to 300 nm pore diameter range. The pore size must be determined by porosity measurements by the awardee prior to delivery to NIST.

Phase II Activities:

During Phase II, support and coating development steps will be integrated. The coating and solid support will be combined by the awardee and evaluated as a function of predicted and measured number density of reactive sites and the measured mean pore diameter in collaboration with the NIST technical contact. A suitable performance metric for the yield, purity, and throughput of the coated substrate will be proposed by the company and developed jointly by the company and the NIST technical contact. This metric will be evaluated experimentally and the optimal range of support and coating properties determined.

Phase II Deliverables:

The awardee will prepare and make available to NIST a series of at least five functionalized solid support materials in multi-gram quantities with well-characterized types and densities of active sites. These materials will be evaluated by NIST for subsequent development of measurement methods and as the possible basis for a future NIST Reference Material. It is anticipated that the awardee will choose to employ the characterization methods and modeling approaches established in this SBIR in the technical development of their commercial product line.

We anticipate that it will be necessary for the company and the NIST technical contact to consult and collaborate closely on a regular basis prior to the delivery of the desired solid material samples.

**9.02.12.73-R Workflow Engine for Smart Manufacturing**

Much of the world now runs on apps. Apps are a marriage of real-world services with IT services. They are pieces of software that live in cyberspace. They frequently perform a small number of simple functions. They are designed for human use today; but soon they will be usable and composable automatically by workflow engines to perform complicated functions.

Manufacturing is behind the rest of the world, but it is catching up. Smart manufacturing is a relatively new term that provides a future vision for manufacturing. That vision harnesses the power of networking, IT, advanced robotics, wireless communications, and ubiquitous sensing to (1) enable adaptive/predictive control of production systems, (2) enable innovative production and products, and (3) enhance economic performance.

Smart manufacturing will provide the impetus and foundation to combine many manufacturing functions with IT services to produce a wide range of manufacturing apps. The availability of such apps will cause a paradigm shift in manufacturing. NIST has initiated a project to develop an architecture that supports the composition and integration of manufacturing apps with each other and with factory control systems. A workflow engine is at the heart of that architecture. Such a workflow engine does not exist today.

A workflow is a sequence of apps that executes parts of, or all of, a given manufacturing engineering process. The workflow engine creates this sequence and manages the execution and integration of its constituent apps with other apps and the rest of the manufacturing environment. These apps may be locally deployed, inside a given factory, or reside in cyber space.

A number of such engines, and associated software tools, are on the market. They typically are not designed to run with apps and they rarely deal with integration problems. This project is to develop the requirements for, an architectural design for, and a software tool for such a smart manufacturing workflow engine.

Phase I Activities:

* Develop requirements for a smart manufacturing workflow engine.
* Analyze existing workflow engines and perform a gap analysis.
* Develop architecture for a smart manufacturing workflow engine.

Phase I Deliverables:

* Document describing smart manufacturing workflow requirements.
* Document describing analysis of and gaps in existing workflow engines.
* Document describing smart manufacturing workflow architecture.

Phase II Activities

* Develop prototype, workflow software tool based on architecture.
* Select a smart manufacturing test case.
* Conduct demonstration of tool using selected test case.
* Modify prototype tool as needed.

Phase II Deliverables:

* Document describing the test cases, results of demonstration, and required changes to initial prototype.
* Document describing capabilities of final tools and scope of use.

NIST is available for collaboration and discussion.

Reference:

1. <https://smart-process-manufacturing.ucla.edu/presentations-and-reports>.