FY 2011
Small Business Innovation Research Program

SOLICITATION

U.S. DEPARTMENT OF COMMERCE

National Institute of Standards and Technology

Opening Date: November 4, 2010

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NIST – 11 – 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 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. Currently the SBIR program has not been reauthorized but Congress has extended the program under a continuing resolution.

Subsequent continuing resolution legislation has extended the program through January 31, 2011. Note: The evaluation of proposals, source selection, and award of contracts under the solicitation is contingent upon the continued existence of the SBIR program. It is anticipated that future legislation will extend the program until it is reauthorized. 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 aligned with the legislated purposes of the program which include stimulating technological innovation in the private sector and strengthening the role of small business in meeting Federal research and development (R&D) needs. It also seeks to increase the commercial application of innovations derived from Federal research and improve the return on investment from federally funded research for the economic benefit of the Nation. 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 awardee whenever possible.

Subtopics listed in Section 9 of this Solicitation each are annotated with either an “R” or a “TT.”

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 while holding the potential for commercial application beyond NIST for the successful awardee.

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. While NIST Laboratory scientists conduct breakthrough research that leads to innovations, the range of NIST’s effort does not extend to product development in any of its intramural research areas. The remaining work needed to fully exploit NIST technologies for commercial viability necessarily requires innovation on behalf of the private sector. As with all SBIR awards, these “TT” subtopics are intended to cultivate private sector innovation. Specifically, each “TT” subtopic identifies a commercially promising NIST technology and the technological gaps that must be filled in order to transition it to the marketplace.

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. All offerors submitting proposals addressing a subtopic that cites background patented technology must submit a non-exclusive, royalty-free license application which is available at the **NIST SBIR website**. Only those non-exclusive, royalty-free research license applications accompanying proposals that result in an SBIR award under this solicitation will be granted.

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

The "Small Business Research and Development Enhancement Act of 1992", as amended, 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.

This solicitation document requests Phase 1 proposals only.

NIST has the unilateral right to select SBIR research topics and awardees in both Phase 1 and Phase 2. As funding is limited, NIST reserves the right to select and fund only those proposals deemed to be superior in overall technical quality and highly relevant to the NIST mission. As a result, NIST may fund more than one proposal in a specific topic area. Similarly, NIST may decide not to fund any proposals in a given topic area.

1.02.01 Phase 1 - Feasibility Research

The purpose of Phase 1 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. Feasibility is a prerequisite to further support in Phase 2.

1.02.02 Phase 2 - Research and Development

Only firms that receive Phase 1 awards under this solicitation will be given the opportunity of submitting a Phase 2 proposal following completion of Phase 1. Instructions for Phase 2 proposal preparation and submission will be provided to Phase 1 awardees typically during the fourth month of the Phase 1 period of performance.

Phase 2 is the R&D or prototype development phase. It will require a comprehensive proposal outlining the research in detail. Further information regarding Phase 2 proposal requirements will be provided to all firms receiving Phase 1 awards.

1.02.03 Phase 3 - Commercialization

In Phase 3, it is intended that non-SBIR capital be used by the small business to pursue commercial applications of Phase 2.

1.03 Manufacturing-related Priority

Executive Order (EO) 13329 "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 research and development (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**.

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: scientific and technical merit, and the potential for commercial success.

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.

1.05 Eligibility

Each organization submitting a proposal for both Phase 1 and Phase 2 must qualify as a small business concern (**Section 2.12**) for research or R&D purposes (**Section 2.9**) at the time of award for each phase. 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. More than one-half of the principal investigator's time must be spent with the small business for the period covered by the award. Primary employment with a small business precludes full-time employment with another organization.

Also, for both Phase 1 and Phase 2, the work must be performed 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, agencies may allow that particular portion of the Research or R&D work to be performed or obtained in a country outside of the United States. Approval by the funding agreement officer after consultation with the agency SBIR Program Manager/Coordinator for each such specific condition must be in writing.

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.

For Phase 1, a minimum of two-thirds of the research and/or analytical effort must be performed by the awardee. For Phase 2, 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 listed herein are not eligible for SBIR awards. Only proposals that are directly responsive to the subtopics as described in Section 9 will be considered.

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 discussion group located at **http://www.nist.gov/sbir**. Discussion group questions will be routed to the appropriate person for a response. All questions and responses will be publicly, though anonymously, posted on the discussion group web site.

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; and

Have not been the recipient of any information on the subtopic not available in the solicitation or other public means; and

Have not received any assistance from DOC in preparing the proposal (including any 'informal' reviews) prior to submission.

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

Requests for general information on the NIST SBIR program may be addressed to:

SBIR Program
100 Bureau Drive, Stop 2200
Gaithersburg, MD 20899-2200

Telephone: (301) 975-6691, Fax: (301) 975-3482
email: **sbir@nist.gov**

For information on contractual issues contact:

Monique Leigh
Acquisition Management Division
Telephone: 301-975-5935
E-mail: monique.leigh@nist.gov

Mario Checchia
Acquisition Management Division
Telephone: (301) 975-8407 Fax: (301) 975-8884
Email: **mario.checchia@nist.gov**

2.0 DEFINITIONS

2.01 Commercialization

The process of developing marketable products or services and producing and delivering products or services for sale (whether by the originating party or by others) to the Government or commercial markets.

2.02 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.

2.03 Feasibility

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

2.04 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.

2.05 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.

2.06 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.

2.07 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.

2.08 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.

2.09 Research or Research and Development

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.

2.10 SBIR Technical Data

All data generated during the performance of an SBIR award.

2.11 SBIR Technical Data Rights

The rights an SBC obtains in data generated during the performance of any SBIR Phase 1, Phase 2, or Phase 3 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.

2.12 Small Business Concern (SBC)

A concern that, on the date of award for both Phase 1 and Phase 2 funding agreements:

(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.

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.

2.13 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.

2.14 Subcontract

This is 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.

2.15 Women-Owned Small Business

A small business concern that is at least 51% owned and controlled by a woman or women in accordance with 13 CFR 127.200, 127.201, and 127.202.

3.0 PROPOSAL PREPARATION GUIDELINES

3.01 Proposal Requirements

NIST reserves the right to not submit to technical review any proposal which it determines has have 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 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 services that 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. The complete proposal application must contain four copies of the following:

(a) Cover Sheet (required form, see **Section 8.0**)

(b) Project Summary (required form, see **Section 8.0**)

(c) Technical Content

(d) Proposed Budget (required form, see **Section 8.0**)

One original proposal – this includes original signatures in each of the three required forms along with the technical section - plus three copies of the proposal are required.

3.02 Phase 1 Proposal Limitations

Page length must be **no more than 25 pages**. Each page is to be consecutively numbered, including the cover sheet (2 pages count as one – for the cover sheet only), project summary, main text, references, resumes, any other enclosures or attachments, and the proposal summary budget. The only exception to the page count limitation are those pages necessary to comply with the itemization of prior SBIR phase 2 awards, per **Section 3.03.03.02**.

Paper size used for the submission must be 21.6 cm X 27.9 cm (8 ½" X 11"). Print size used for the submission must be easy to read with a fixed pitch font of 12 or fewer characters per inch or proportionally spaced font of point size 10 or larger with no more than 6 lines per inch.

Supplementary material, revisions, substitutions, audio or video tapes, or computer floppy disks will **not** be accepted. If submitted these items will not be reviewed by evaluators.

The original and all copies of each proposal must be mailed in one package. **The bottom right corner of the outside of the package must be clearly marked "SBIR – Subtopic**

(fill in the subtopic # ________)".

3.03 Instructions for Phase 1 Proposal Submission Forms and Technical Content

This section includes instructions for completing each of the three required forms as well as the format required for the Technical Content section. A complete proposal application must include four copies of each of the following: **Cover Sheet**, **Project Summary**, Technical Content (up to 22 pages), and **Proposed Budget**. Any applications received missing any of these required items will be returned without review.

3.03.01 Cover Sheet

Complete all items in the "Cover Sheet" required form and use as page 1 of the proposal. Please ensure that required signatures on page 1b are included. No other Cover Sheet will be accepted.

Before NIST can award a contract to a successful offeror under this solicitation, the offeror must be registered in the DoD Central Contractor Registration (CCR) database. The CCR allows Federal Government contractors or firms interested in conducting business with the federal government to provide basic information on business capabilities and financial information. To register, visit **http://www.ccr.gov** 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 small business concern without registration in CCR and a DUNS number.

Offerors are cautioned to identify proposal page numbers that contain their confidential information in the Proprietary Notice section at the end of the Cover Sheet.

3.03.02 Project Summary

Complete all sections of the "Project Summary" form 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. Keywords should be chosen to describe the proposed work both generally and specifically. 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 by NIST and, therefore, must not contain proprietary information.**

3.03.03 Technical Content

Commercialization of SBIR research results is an important factor in the evaluation of all proposals. Because of the nature of the "TT" subtopics, special attention must be given to identify not only the technical approach to the research problem identified in the subtopic but the proposed means for commercializing the core NIST technology being exploited through the proposed research.

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

(a) **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.

(b) **Phase 1 Technical Objectives.** State the specific objectives of the Phase 1 effort, including the technical questions it will try to answer, to determine the feasibility of the proposed approach.

(c) **Phase 1 Work Plan**. Include a detailed description of the Phase 1 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 methods planned to achieve each objective or task should be discussed in detail. This section should be at least one-third of the proposal.

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.

(d) **Related Research or R&D.** Describe research or R&D that is directly related to the proposal, including any conducted by the principal investigator or by the offeror. 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.

(e) **Key Personnel and Bibliography of Related Work.** Identify key personnel involved in Phase 1, including their related education, experience, and publications. Where resumes are extensive, summaries that focus on the most relevant experience and publications are suggested. List all other commitments that key personnel have during the proposed period of contract performance.

(f) **Relationship with Future R&D.** Discuss the significance of the Phase 1 effort in providing a foundation for the Phase 2 R&D effort. Also state the anticipated results of the proposed approach, if Phases 1 and 2 of the project are successful.

(g) **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 1. **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.

(h) **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. Outside involvement is limited to no more than 1/3 of the research and/or analytical effort in Phase 1, 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.

Absence of such documents explaining such a consultant or subcontract, if cited elsewhere in the proposal and/or the budget, may disqualify the offeror from consideration.

No individual or entity may serve as a consultant or subcontractor if they:

Had any role in suggesting, developing, or reviewing the subtopic; or

Have been the recipient of any information on the subtopic not available to the public.

(i) **Potential Commercial Application.** Describe in detail the commercial potential of the proposed research, how commercialization would be pursued and potential use by the Federal Government.

(j) **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.

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

(l) **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 1. NIST will not consider whether an offeror proposes cost sharing in its evaluation of proposals

3.03.03.01 Similar Proposals or Awards

NOTE - 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 an offeror elects to submit identical proposals or proposals containing a significant amount of essentially equivalent work under other Federal program solicitations, a statement must be included in each such proposal indicating:

(i) The name and address of the agencies to which proposals were submitted or from which awards were received.

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

(iii) Title, number, and date of solicitations under which proposals were submitted or awards received.

(iv) The specific applicable research topics for each proposal submitted or award received.

(v) Titles of research projects.

(vi) 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.

3.03.03.02 Prior SBIR Phase 2 Awards

If the small business concern has received more than 15 Phase 2 awards in the prior five fiscal years, it must submit in its Phase 1 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 2 award. This required information shall not be part of the 25 page count limitation.

3.03.04 Proposed Budget

NIST will not issue SBIR awards that include provisions for subcontracting any portion of the contract back to the federal government.

For Phase 1, a minimum of two-thirds of the research and/or analytical effort must be performed by the proposing small business concern. For Phase 2 a minimum of one-half of the research and/or analytical effort must be performed by the proposing small business concern.

Complete the Proposed Budget required form for the Phase 1 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.

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 D. 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. Otherwise include 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 1 and 2 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 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. It also may elect to fund several or none of the proposed approaches to the same topic or subtopic.

4.02 Phase 1 Screening Criteria

Phase 1 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 1 proposal must meet **all** of the requirements stated in **Section 3.0**.

(c) The Phase 1 proposal must be limited to one subtopic and clearly address research for that subtopic.

(d) Phase 1 total proposal budget must not exceed $90,000.

(e) The feasibility research duration for the Phase 1 project must not exceed 6 months.

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

4.03 Phase 1 Evaluation Criteria

Phase 1 proposals that comply with the screening criteria will be rated by NIST scientists or engineers in accordance with the following criteria:

(a) The scientific and technical merit of the proposed research (25 points)

(b) Innovation, originality, and feasibility of the proposed research (20 points)

(c) Relevance and responsiveness of the proposed research to the subtopic to which it is addressed (20 points)

(d) Quality and/or adequacy of facilities, equipment, personnel described in the proposal (15 points)

(e) Quality of the proposal's commercialization potential as evidenced by the offerors record of commercializing other research products; existence of outside, non-SBIR, funding or partnering commitments; or the presence of other indicators of commercial potential of the idea (20 points)

Technical reviewers will base their ratings on information contained in the proposal. It cannot be assumed that reviewers are acquainted with any experiments referred to, key individuals, or the firm. No technical clarifications may be made after proposal submission.

Final award decisions will be made by NIST based upon ratings assigned by reviewers and consideration of evaluation of additional factors such as possible duplication of other research, the importance of the proposed research as it relates to NIST needs, 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 1 award, NIST reserves the right to negotiate the amount of the award.

4.04 Phase 2 Evaluation Criteria

During the feasibility study project performance period, Phase 1 awardees will be provided instructions for preparation and submission of Phase 2 proposals. Phase 2 proposals that comply with the screening criteria as stated in those instructions will be rated by NIST scientists or engineers in accordance with the following criteria:

1. Degree to which Phase 1 objectives were met (25 points)

2. The scientific and technical merit of the proposed research, including innovation, originality, and feasibility (25 points)

3. Quality and/or adequacy of facilities, equipment, personnel described in the proposal (25 points)

4. Quality of the proposal's commercialization potential as evidenced by either the offerors record of commercializing other research products, existence of outside, non-SBIR, funding or partnering commitments, or the presence of other indicators of commercial potential of the idea. (25 points)

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 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 24 Phase 1 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 2 awards shall be for no more than $300,000. The R&D activity period of performance in Phase 2 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 expected to report on their commercialization activities. The total period of performance for Phase 2 is 37 months.

It is anticipated that approximately one-fourth of the Phase 1 awardees will receive Phase 2 awards, depending upon the availability of funds. To provide for an in-depth review of the Phase 1 final report and the Phase 2 proposal and commercialization plan, Phase 2 awards will be made approximately 5 months after the completion of Phase 1, contingent upon availability of funds.

This solicitation does not obligate NIST to make any awards under either Phase 1 or Phase 2. Furthermore, NIST is not responsible for any monies expended by the offerors before awards are made.

Upon award, the awardee will be required to make certain legal commitments through acceptance of numerous clauses in Phase 1 funding agreements. 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 1 funding agreements, and is not the specific wording of such clauses. Copies of complete terms and conditions are available upon request.

These statements 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.

5.02 Reports

Progress reports scheduled periodically during the Phase 1 and Phase 2 periods of performance 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 5.05.03**.

An R&D final report on the Phase 2 project shall be submitted to NIST within 30 calendar days after completion of the two-year Phase 2 R&D activity period. A commercialization update report on the SBIR project shall be submitted to NIST within 30 calendar days three years after the Phase 2 award date, i.e. one year after the completion of the two-year Phase 2 R&D activity period. The total period of performance for Phase 2 is 37 months.

Final reports submitted under Phase 1 and Phase 2 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 commercialization update report will include the target markets and customers that have been identified for the technology developed under the SBIR project. The report shall include details about additional activities that have been planned and executed along with future plans to derive revenues from the technology; these may include but are not limited to: pricing, partners, licensing, production plans, manufacturing partners, follow-on R&D funding. Resources committed by the awardee to effectively commercialize technologies developed under the SBIR project will be clearly demonstrated as well as projections for further commercialization. Further details regarding the exact requirements for the commercialization update report will be provided during the Phase 2 period of performance.

5.03 Deliverables

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.

5.04 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.

NIST will allow the Phase 1 award amount to be paid on a bimonthly interim basis upon delivery and technical acceptance by NIST of three progress reports that describe services performed, and one final $5,000 payment upon delivery and technical acceptance of the final report.

NIST will allow the Phase 1 award amount to be paid on a bimonthly interim basis upon delivery and technical acceptance by NIST of three progress reports that describe services performed, and one final payment upon delivery and technical acceptance of the final report.

NIST will allow the Phase 2 award amount minus $10,000 to be paid in five equal increments on an interim basis upon delivery and acceptance of four progress reports (at the 2nd, 6th, 12th, and 18th months of the project) that describe services performed, and one final equal increment payment upon delivery of the final R&D report and prototype, if applicable per subtopic requirement, at the 25th month of the project. The final $10,000 will be paid upon delivery and acceptance of the commercialization update report at the 37th month of the project. Failure to submit the report within thirteen months of the completion of the R&D activity period for Phase 2 will result in a de-obligation of the $10,000.

5.05 Proprietary Information, Inventions, and Patents

5.05.01 Limited Rights Information and Data

Information contained in unsuccessful proposals will remain the property of the offeror. Any proposal which is funded will not be made available to the public, except for the "Project Summary" page.

The inclusion of proprietary information is discouraged unless it is necessary for the proper evaluation of the proposal. 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 first page of the technical section 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.

Examples of laws that restrict the government to protect confidential/proprietary information about business operations and trade secrets possessed by any company or participant include: Freedom of Information Act (FOIA)—5 U.S.C. § 552(b); Economic Espionage Act—18 U.S.C. § 1832; and Trade Secrets Act—18 U.S.C. § 1905.

In view of the above, proposers 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.

5.05.02 Copyrights

The contractor may normally establish claim to copyright any written material first produced in the performance of an SBIR contract. If a claim to copyright is made, the contractor shall affix the applicable copyright notice of 17 U.S.C. 401 or 402 and acknowledgment of Government sponsorship (including funding agreement number) to the material when delivered to the Government, as well as when the written material or data are published or deposited for registration as a published work in the US Copyright Office. For other than computer software, the contractor gives to the Government, and others acting on its behalf, a paid-up, nonexclusive, irrevocable, worldwide license to reproduce, prepare derivative works, distribute copies to the public, and perform publicly and display publicly, by or on behalf of the Government.

For computer software, the contractor gives to the Government a paid-up, nonexclusive, irrevocable, worldwide license for all such computer software to reproduce, prepare derivative works, and perform publicly and display publicly, by or on behalf of the Government.

5.05.03 Rights in Data Developed Under SBIR Contracts

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:

SBIR RIGHTS NOTICE

"These SBIR data are furnished with SBIR rights under Contract 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."

(END OF NOTICE)

The Government's sole obligation with respect to any properly identified SBIR data shall be as set forth in the paragraph above.

5.05.04 Patents

Small business concerns normally may retain the principal worldwide patent rights to any invention developed with Government support. 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 requires that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically. To the extent authorized by 35U.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**.**

5.05.04.01 NIST-Owned Patented Background Inventions

SBIR awards made subsequent to "TT" subtopics in this Solicitation, will, upon the request of 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 Section 5.05.04.

5.05.05 Invention Reporting

SBIR awardees must report inventions to the NIST SBIR Program within 2 months of the inventor's report to the awardee. The reporting of inventions may be accomplished by submitting paper documentation, including fax or through the iEdison Invention Reporting System at **www.iedison.gov.**

5.06 Additional Information

(1) 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.

(2) Before award of an SBIR funding agreement, the Government may request the offeror to submit certain organizational, management, personnel, and financial information to assure responsibility of the offeror.

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

(4) 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.

(5) 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 1 or Phase 2.

(6) 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.

(7) 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.

(8) 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 1 proposal.

5.07 Research Projects with Human Subjects, Human Tissue, Data or Recordings Involving Human Subjects

Any proposal that includes research involving human subjects, human tissue, data or recordings involving human subjects must meet the requirements of the Common Rule for the Protection of Human Subjects, codified for the Department of Commerce at 15 CFR Part 27. In addition, any proposal that includes such research on these topics must be in compliance with any statutory requirements imposed upon NIH and other federal agencies regarding these topics, all regulatory policies and guidance adopted by NIH, FDA, and other federal agencies on these topics, and all Presidential statements of policy on these topics.

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**.

5.08 Research Projects Involving Vertebrate Animals

Any proposal that includes research involving vertebrate animals (including fish) 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, 2101 Constitution Avenue, NW, Washington, D.C. 20055. In addition, such proposals must meet the requirements of the Animal Welfare Act (7 U.S.C. 2131 et seq.), 9 CFR Parts 1, 2, and 3, and if appropriate, 21 CFR Part 58. These regulations do not apply to proposed research using pre-existing 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.

6.0 SUBMISSION OF PROPOSALS

6.01 Deadline for Proposals

Deadline for Phase 1 SBIR proposal receipt is 3:00 pm on Friday, January 28, 2011 at the Contracts Office address below.

NIST does not accept electronic submission of proposals.

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.

If proposals are to be hand delivered prior to the due date, delivery must be made by the actual deadline date and a 24-hour notice must be made to the NIST Contracts Office prior to delivery. All Offerors must notify Monique Leigh at 301-975-5935 or monique.leigh@nist.gov. The name of the individual or courier company making the delivery must be included in the notification.

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 (FAR 52 215-1) regarding late proposals shall apply.

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

If courier delivered, the Offeror must submit the Proposal Packages (four (4) copies) as defined in **Section 3.03** to:

National Institute of Standards and Technology
Acquisitions and Management Division
Attn: Monique Leigh, NIST-11-SBIR
100 Bureau Drive STOP 1640 Building 301, Room BC146
Gaithersburg, MD 20899-1640

Phone Number: (301) 975-5935

Hand delivery will be accepted ONLY at the following location on the due date, Friday, January 28, 2011, from 8:00 AM EST until closing time at 3:00 PM EST:

National Institute of Standards and Technology
100 Bureau Drive (Off Clopper Road)
Visitor Center ONLY
Gaithersburg, MD 20899

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.

(a) Packaging--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. Clearly mark the bottom right-hand corner of the package with the subtopic number to which the proposal is responding.

(b) Bindings--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**. 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

8.01 Click on this link: **Cover Sheet** in order to access the required form (2 pages) in pdf format.

8.02 Click on this link: **Project Summary** in order to access the required form in pdf format.

8.03 Click on this link: **Proposed Budget** in order to access the required form 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 3:00p.m. EST January 28, 2011.**

1. The **Cover Sheet** (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** is page 2 of the proposal. The abstract contains no proprietary information.

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

4. The **Proposed Budget** 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 21.6cm X 27.9cm size (8 ½" X 11").

8. The proposal contains an easy-to-read font (fixed pitch of 12 or fewer characters per inch or proportional 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.

10. If proposal addresses a subtopic that depends on patented background NIST technology, a non-exclusive, royalty-free patent license **application** is required. One signed original application is to be sent with the proposal package. Each subtopic that references patented background technology and requires a license application is denoted with an asterisk.

NOTE: 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** 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 Q&A 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

9.01 Bioscience and Health

9.01.01.63-R Instrument for Characterization of Environmental Soot Aggregates

Particulate matter in the environment is known to have a significant influence on the climate, air quality, and population health. We are currently developing a program to investigate nano-particle effects on health. One of the diagnostic tools to be used in this project is laser-induced incandescence (LII), which can provide quantitative information on particle primary size and volume fraction. We currently have a turn-key system to provide real-time, nonintrusive measurements of these soot characteristics; however, LII measurements are unable to provided information on the soot aggregate characteristics (i.e., soot primary particle size and number density, volume fraction, fractal dimension, aggregate size distribution assuming a log-normal distribution function). We are interested in characterizing the aggregate fractal nature by using Rayleigh-Debye-Gans light scattering theory to treat the nonspherical nature of soot aggregates as a polydisperse collection of mass fractal aggregates, as described by Faeth and Koylu [Combustion, Science and Technology, 1995], and thus is the only approach that will considered for our LII. The analysis must takes into account the need to optimize the scattering angles and wavelengths of light to be monitored for obtaining measurements successfully in the power-law and Guinier regimes. A multilayered approach must be used that includes Matlab models based on RDG/PFA theory, an inversion scheme for the laser extinction/scattering at different wavelengths, a direct method to measure the angular scattering, and a counting method to measure the soot aggregate size. We seek a diagnostic system that provides state-of-the-art analysis of aggregate/agglomerate characteristics for particles as large as 10 microns, and the hardware will be integrated with our current LII system. The software must provide access to the raw data so that post processing of statistical information and graphing of data can be carried out on other computing platforms.

Phase 1 should demonstrate the feasibility of this new diagnostic to meet the stated criteria. The objective of Phase 2 is the delivery of a functioning instrument that is integrated into our current LII system. It is expected that this new measurement capability will find immediate commercial applications for a wide range of environmental and health-related technologies.

NIST staff will be available for consultation and input if needed.

9.01.02.63-TT Instrument for Detection of Inhaler Dose Concentration

Little quantitative information on spatially or temporally resolved concentration of a drug throughout the aerosol (i.e., presence of the active pharmaceutical ingredient (API) within any particular liquid droplet or solid particle) is available; concentration along with size is critical for proper dosage and transport efficiency to the site of action. We have developed a measurement approach to obtain dose concentration of pharmaceutical-laden, multiphase aerosols [1]. Since many biological molecules either are naturally fluorescent or can be chemically modified with fluorophores, one can relate fluorescence intensity to concentration (or mass) of these inclusions within the droplet volume. The approach used distinguishes between aerosol droplets that may or may not contain fluorescing agent (i.e., to identify droplet-to-droplet variations in agent concentration). Development of a functioning prototype instrument is needed that integrates the measurement of both particle and droplet fluorescence intensity with image splitting technology and magnification optics.

Proposals will only be considered if it can be demonstrated that the capability already exists to 1) image and record fluorescence and scattering intensity of individual droplets, 2) determine API drug fluorescence by fluorescence spectrophotometry, 3) prepare solutions with API to prove that natural fluorescence can be used to identity API in a solution or mixture, 4) image and distinguish fluorescent and non-fluorescent microspheres (of comparable size to droplets in metered-dose inhalers) using fluorescence microscopy, 5) extract and identify particle size, scattering and fluorescence intensity from recorded images using an already existing mathematical algorithm, and 6) form composite images of the combined scattering and fluorescence images. To be considered, commercially available equipment must have been identified and a prototype design developed that accounts for use of different types of manufactured inhalers. Expected instrument operating parameters are droplet range of interest is between 1 μm and 10 μm, API concentration of 0.2 g/L – 1.0 g/L, total test time < 1 min, instrument response time < 1 s, maximum flow rate of 15 L/min, volume/dose of 50 μL – 100 μL, and droplet flow speed of 1 m/s – 10 m/s.

Phase 1 should demonstrate the availability and experience with the above expectations, and address experimentally other potential issues that need to be considered for developing a functioning prototype instrument.

The objective of Phase 2 is the delivery of a functioning prototype device. It is expected that this new measurement capability will find immediate commercial applications for a wide range of healthcare technologies. It is expected that research will be collaborative with NIST during both phases of the research, including coauthoring manuscripts to be submitted for archival publication.

[1] Presser, C., "Detection of Dose Concentration in Droplets Generated by Pulmonary Drug Delivery Devices," 21st Annual Conf. on Liquid Atomization and Spray Systems (ILASS Americas 2008), on CD, Orlando, FL, 2008.

9.02 Chemistry/Mathematics/Physics

9.02.01.63-R Signal Processing Methods for High-Dimensional Microsensor Data Streams

There exists a growing need for gas phase chemical analyses that can be performed reliably by portable systems. The application areas driving these needs are highly diverse, ranging from long-term environmental monitoring and process control to homeland security and medical diagnostics. Sensors and microsensors are expected to fulfill the detection role for many of the numerous application sectors, often because instruments (even when they can be miniaturized) are too expensive and/or labor intensive, and because they cannot be easily configured into network monitoring schemes.

This demand for sensors creates a significant set of challenges for sensor and microsensor performance. They must also be able to work under differing background conditions and identify a wide variety of target species. In fact, many applications (e.g. - personal safety or breath analysis for health screening) require that very low levels (~ 1 ppb to 100 ppb) of target compounds be tracked against complex and dynamic backgrounds that are mixtures of 10's to 100's of chemicals. Recognition, classification and quantification of the target analytes in such situations by sensors (not spectroscopic instruments) can require extremely rich datastreams as well as signal processing techniques that extract critical analytical information efficiently, rapidly and successfully.

NIST seeks the design and development of high performance signal processing routines to mate with microsensor technology being developed at its Gaithersburg, MD campus. Rich signal streams are produced from multielement (9 to 36) arrays, which are controlled and interrogated via circuitry that can individually address each element and also modulate the transduction properties of each microsensor within the arrays. Varied sensing materials populate the arrays so that differing responses are produced [1]. An example of "higher dimensionality" modulation of the elements is temperature programming (over a range of ~ 450 °C in 10 s), which temporally alters interfacial phenomena contributing to orthogonal signals coming from the sensor elements [2]. Data from a 16-element array can be obtained at a rate of up to ~ 200/s, with tests lasting weeks or even months. Training/testing sequences can also be rich in the variety of conditions they seek to examine (moving through ~ 40 conditions with specific exposure times of minutes). Signal processing methods are required that can model responses under known conditions, and then use those models for recognition of species during test sequences. It is expected that successful signal analysis will also require signal preprocessing subroutines that adapt to certain levels of signal offset and drift in order to track useable response (shape) features. The models and signal analysis must quickly probe the rich datastreams to locate the most useful data for recognizing chemical events in time, discriminate between test flow constituents, and then identify and quantify target compounds. Certain aspects of the NIST technology can also benefit from software capabilities for tracking microsensor element "fatigue". Ultimately, the signal processing software would be refined to operate with the sensing hardware for near-real time detection and quantification. Many mathematical approaches can be considered to achieve these tasks, but it is imperative that the selected components work effectively together in the assembled signal processing system.

To make any award under this program most beneficial, NIST researchers will work closely with performers to provide databases that will be used in the development project.

Databases will be delivered for both training and testing experiments. Provided data will be accompanied by full descriptions of the experimental protocol and an explanation of any special operational aspects programmed into the microsensors in order to enrich or supplement the signal stream. During Phase 1, the awardee would develop methods for determining the most valuable portions of the data as a means of constructing recognition algorithms, and as appropriate, target libraries. Recognition models would be delivered to NIST, initially for off-line testing, and after refinements including integration with the NIST sensor control system, for on-line testing. Success would be measured by percentage of target analyte recognition the model allows (for multiple "on-off" presentations of from 3 to 4 compounds) in on-line testing demonstrations under a variety of backgrounds (including several interferences). Recognition from the coupled hardware-signal processing system must be indicated within 6 operational cycles (typical cycles running from 15 s to 30 s).

Phase 2, if awarded, would seek to improve the performance of the signal processing software, in terms of both percentage of proper recognition of targets, and the speed with which those assignments are made (down from 6 operational cycles to 3 cycles). In addition, NIST would require the demonstration of a number of other features, including a target quantification software module, flexibility to respond to adaptive operational modes, and a sensor fatigue tracking metric. Close collaboration with NIST researchers is envisioned for optimization of the system efficiency.

References:
1. K. D. Benkstein and S. Semancik “Integration of Nanostructured Materials with MEMS Microhotplate Platforms to Enhance Chemical Sensor Performance”, Journal of Nanoparticle Research 8, 809-822 (2006).

2. D. C. Meier, J. K. Evju, Z. Boger, B. Raman, K. D. Benkstein, C. J. Martinez, C. B. Montgomery, and S. Semancik, “The Potential for and Challenges of Detecting Chemical Hazards with Temperature-Programmed Microsensors”, Sensors and Actuators B 121, 282-294 (2007).

9.03 Electronics and Telecommunications

9.03.01.68-R Parallel Signal-Processing System for High-Resolution Tomography

Our interest is in time-resolved, three-dimensional mapping of radiation dose fields. This pertains to dose monitoring in irradiated materials and scattering environments, and treatment planning for intensity-modulated radiotherapy (IMRT) beams. The metrological challenge posed by time-resolved dose mapping of IMRT beams is particularly difficult, since the direct assessment of radiotherapeutic dose entails measuring temperature changes in the 10s to 100s of microkelvin.

Recently, high-precision ultrasonic time-of-flight techniques, which are ubiquitous in nondestructive testing and measurement, were employed successfully to measure radiation-induced temperature changes in water with a precision of a few microkelvin [1]. Subsequent work on this system led to development of a 128-channel, circular ultrasonic array that could image submillikelvin changes in a layer of water of a few cm in diameter at a frame rate of 0.25 Hz, and with a spatial resolution of a few mm [2].

However, limitations to the data acquisition and processing scheme precluded its scaling to a larger cylindrical array, suitable for imaging volumes of interest in radiotherapy with sufficient spatial, temporal, and temperature resolution. Our goal is tomographic reconstructions of a three-dimensional temperature field in water, with microkelvin-level precision over a cylindrical volume of diameter 15 cm and depth of 15 cm, with a spatial resolution better than 1 mm in each dimension, and with a frame rate of 1 Hz or faster. This would require resolution of probe-pulse arrival times to a precision of 10 ps or better.

The present solicitation is for developing a scalable data acquisition and processing architecture that would interface with the existing 128-element array, but which could be used with larger arrays in the future. As detailed in [2], hardware switching speeds, propagation delays in the target medium, and limits to computer-bus bandwidth limited the frame rate of images derived from the 128-channel array. With arrays containing 10 to 100 times as many channels being envisioned for an ultimate instrument, a much more efficient data-processing architecture is needed. The present solicitation is for the development of a parallel, multichannel data acquisition and processing system that would enable such advances.

Such a system would share design issues with others that must also take signal multipath and interference effects into account. It is reasonable to suppose that signal multiplexing and deconvolution schemes that have been successfully employed in other disciplines can find application here as well. We invite proposals that explain such cross-disciplinary approaches. Indeed, this has been explored in smaller systems with coarser time resolution than what is envisioned here [3].

Phase 1 – prototype system deliverable to NIST that would allow parallel, simultaneous acquisition and processing with the existing 128-element ultrasonic array in water at the desired frame rate and with picosecond-level time resolution. Ideally, the system would allow for the testing of various multiple-access approaches, including maximum-length pseudorandom sequences, which could prove to be promising. Besides the requirements for high space- and time-resolution, the fact that this is a calorimetry system intended for dosimetry of therapy-level radiation beams poses additional constraints on candidate hardware and software (e.g. heating of the water by ultrasonic power dissipation must be negligible).

Phase 2 – a modified prototype or alternative design with similar objectives (to that of Phase 1) suitable for arrays containing 1,000 to 10,000 transducers, also deliverable to NIST.

It is anticipated that the work to be carried out for this project would provide a scalable, image processing technology that could be readily adapted to other types of signals and transducer systems; thus, subsequent commercial development need not be restricted to ultrasonic or acoustic markets.

NIST staff will be available to work collaboratively with the awardee.

References:
[1] "High resolution ultrasonic thermometer for radiation dosimetry," Eugene V. Malyarenko, Joseph S. Heyman, H. Heather Chen-Mayer, and Ronald E. Tosh, J. Acoust. Soc. Am. 124 3481–90 (2008).

[2] "Time-resolved radiation beam profiles in water obtained by ultrasonic tomography," Eugene V. Malyarenko, Joseph S. Heyman, H. Heather Chen-Mayer, and Ronald E. Tosh, Metrologia 47 3 (2010).

[3] "Simultaneous acoustic channel measurement via maximal-length-related sequences," Ning Xiang, John N. Daigle, and Mendel Kleiner, J. Acoust. Soc. Am. 117 (4), Pt. 1 (2005).

9.03.02.68-R High-Resolution Optical Pulse Shaper

NIST seeks to develop the science and technology to enable the generation of arbitrary optical waveforms. This addresses the need to extend complex signal processing, including the production and control of electromagnetic waves of arbitrary shape and frequency composition, beyond the current electronic limits of about 100 gigahertz up to the optical range, about 1 petahertz. Optical signal processing—the synthesis and control of light with the same dexterity that electronic signals are currently manipulated—would dramatically expand the power of applications such as communications, surveillance, optical pattern recognition, remote sensing, and high-speed computing.

A crucial feature of processing and controlling electromagnetic signals is the ability to precisely control the amplitude and phase of the waves. At NIST, we aim to accomplish this in the frequency domain through line-by-line amplitude and phase control of an optical frequency comb [1]. In this approach, a critical component is a high-resolution spectral disperser and shaper that can be used to individually control many hundreds of frequency comb modes in a line-by-line fashion.

The present solicitation is for the development of such a spectral disperser and shaper that would employ novel approaches such as compact, high-resolution diffractive/refractive/waveguide dispersers, high-speed modulators, advanced liquid crystals, semiconductors, or optical-MEMS systems.

Desired characteristics of the resulting optical pulse shaper include:

- Operation in the 1550 nm range
- Bandwidth of up to 12 THz (e.g. ~100 nm)
- Resolution better than 3 GHz
- Single-mode fiber coupled with transmission loss <5 dB (input to output)
- $>2\pi$ radians of phase control and >30 dB of attenuation with > 8 bit resolution
- Phase stability better than 0.3 rad on 1 second time scale
- Polarization diverse
- Small footprint (fits in 19” rack)
- Computer-based interface

We recognize that such design goals are challenging and that all of the above characteristics may not be met for a single device.

In Phase 1 the awardee must deliver to NIST a breadboard prototype disperser/shaper as described in the proposal. It will be become property of NIST, and we intend to study it to learn how to further advance the art.

If Phase 1 is successful and if sufficient funding is available, for Phase 2, the awardee must proceed with the development of a fully packaged and integrated dispeser/shaper, with the ultimate goal of commercializing it.

NIST is willing to provide laboratory resources and personnel to aid in the testing and evaluation of the deliverables at the end of each of the respective phases.

Reference:
[1] C.-B. Huang, Z. Jiang, D. E. Leaird, J. Caraquitena, and A. M. Weiner, “Spectral line-by-line shaping for optical and microwave arbitrary waveform generations,” Laser & Photon. Rev. 2(4), pp. 227–248 (2008).

9.03.03.68-R mm-Wave Phase Noise Measurement System Using Photonic Delay-Line

There is considerable need for new phase-noise measurement techniques in the mm-wave range of 26 GHz to 60 GHz. Existing electronic phase-noise measurements at these frequencies require complex schemes involving multiple heterodynes, frequency conversions, multiple ultra-low-noise local oscillators, banks of anti-aliasing filters, and extensive internal and external EMI shields.

A better phase-noise measurement technique, used at NIST, is microwave direct-conversion, sometimes referred to as a homodyne measurement. It uses an optical-fiber delay-line frequency discriminator spanning 6 GHz to12 GHz. The delay-line technique needs neither a reference oscillator nor a phase-locked loop, but rather it time-delays a test RF-oscillator signal that, when combined with the undelayed signal, measures frequency fluctuations at time delay, τ.

Unfortunately, the noise floor of this delay-line discriminator measurement is inversely proportional to τ. By increasing the time delay, the noise floor can be lowered; however, longer delay causes higher insertion loss of the RF signal, which also essentially increases the noise floor. This problem can be overcome by use of a photonic delay line, such as a long optical fiber wound on a spool that carries the RF signal as modulation on an optical carrier (a laser) and subsequently is demodulated at a photodetector. A 6 km fiber typically provides 1.3 dB loss and about 30 μs delay whereas insertion loss due to a 25 m semi-rigid cable at, say, 10 GHz is approximately 20 dB and a delay of only about 100 ns. Using 30 μs photonic delay instead of 100 ns RF delay, almost 40 dB of improvement in noise floor can be achieved.

For longer optical fibers, the noise-floor improvement begins to diminish, until it is set by the τ-delay fluctuations due to environmental inducements, most notably the vibration sensitivity due to normal background. This sensitivity to vibration can become particularly excessive at Fourier, or offset, frequencies close to the operating frequency, as low as 10 Hz. Vibration sensitivity of the delay line is traditionally characterized by acceleration sensitivity and typically produces measurement-related frequency shifts on the order of 10^{-9} per g over a range of vibration frequencies, primarily because of physical deformations of the spool on which the optical fiber is wound. Reduction of vibration sensitivity to below 10^{-11} per g is possible using a stiff spool and centered mounting for 10 Hz < f_v < 2000 Hz, where f_v is the vibration frequency [1].

The present solicitation is for the development and ultimate commercialization of a phase-noise measuring system in the mm-wave range of 26 GHz to 60 GHz based on these principles.

In Phase 1 the awardee must design a method of: (1) achieving direct PM-noise measurements without frequency conversion to at least 40 GHz, (2) obtaining 10^{-11} per g for a 6 km length of fiber-on-spool with optical loss below 1.5 dB at 1550 nm, and (3) achieving a noise floor relative to a +10 dBm test signal that meets or exceeds prevailing electronic systems.

If Phase 1 is successful and if sufficient funding is available, for Phase 2, the awardee must deliver to NIST a PM-noise measurement system based on the design of Phase 1 and using at least one optical delay-line frequency discriminator comprised of a 6 km or longer length of fiber-on-spool.

We do not anticipate working collaboratively with the company to accomplish the project goals, but would be available for consultation on any aspects of the project.

References:

[1] See, e.g., A. Hati, C. W. Nelson, J. Taylor, N. Ashby, and D. A. Howe, “Cancellation of Vibration-Induced Phase Noise in Optical Fibers,” IEEE Photonics Technology Letters, 20(22), pp. 1842–1844 (Nov. 15, 2008);
Online at: **http://tf.boulder.nist.gov/general/pdf/2119.pdf**

9.03.04.68-R Electrical Connectors for Millimeter-Wave Instrumentation

Development of electronics at frequencies above 110 GHz is hampered by a lack of broadband connectors for system integration and test. Large-signal network analyzers provide an example. They are effective new measurement tools that allow circuit designers to “see” the voltages and currents in their design directly, and are an indispensible tool for optimizing nonlinearity and efficiency in transmitter electronics to increase dynamic range and battery life. While large-signal network analyzers are becoming commonplace at cellular and microwave frequencies, accurate large-signal device characterization at millimeter-wave frequencies will require a new connector type that is broadband enough to simultaneously capture fundamental frequencies and harmonics, and flexible enough to allow conventional instrumentation to be integrated into the test sets.

Rectacoax (a.k.a. recta-coax, the better Google search term) transmission lines are microfabricated transmission lines similar to coaxial transmission lines. They are fabricated with a planar process that produces a stack of many planar patterned metal layers. Like coaxial transmission lines, they have a central hollow metal enclosure with a metal center conductor suspended in the center. However, due to the fabrication technology, rectacoax transmission lines have a rectangular cross section. Rectacoax transmission lines can support single-mode propagation from dc to many hundreds of GHz.

The present solicitation is for the development of a new electrical connector type to support large-signal network analyzers and for other purposes at millimeter-wave frequencies. The goal is to develop and commercialize rectacoax connectors, adapters, wafer probes, and chip holders to enable electronic millimeter-wave measurement instrumentation.

In Phase 1 the awardee must demonstrate the ability to connect and disconnect rectacoax connectors at least five times with a return loss of –15 dB or less and a repeatability of at least –30 dB over a 50 GHz bandwidth. Verification of this performance metric must be performed by NIST. The awardee may also wish to fabricate prototypes of the adapters, probes, and circuits that would be required in Phase 2, but do not have to demonstrate their performance.

If these specifications are met and if sufficient funding is available, for Phase 2, the awardee must further refine the connectors, add a full line of adapters, and fabricate the components needed to build a large-signal network analyzer for use at fundamental frequencies to 138 GHz that captures harmonics to 420 GHz. The awardee must demonstrate at least 20 reproducible connections and disconnections between two rectacoax connectors with a return loss of –25 dB or less and a repeatability of –30 dB over a 420 GHz single-mode bandwidth. To accomplish this, the awardee must also fabricate a set of rectacoax to rectangular waveguide adapters covering the band 110 GHz to 420 GHz. Verification of this performance metric must be performed at NIST.

In Phase 2 the awardee must also fabricate a chip holder designed to hold NIST electro-optic samplers with CPW inputs and holes to allow access for the required optical sampling beams. These components are extremely linear and have great dynamic range, and will be used at NIST to demonstrate feasibility of a large-signal network analyzer and other measurement instruments based on this technology for use at fundamental frequencies to 138 GHz that captures harmonics to 420 GHz.

Applicants should specify how they plan to meet or exceed the return loss and repeatability specifications given above, including specifying how they will achieve the electrical and mechanical material properties required to achieve repeatable connections and disconnections.

Applicants are encouraged but not required to propose a working relationship with NIST on the electrical aspects of the designs, but are expected to perform all aspects of the mechanical design tasks themselves. Applicants should specify how they would work with NIST on electrical design and on the incorporation of NIST chips in the designs. NIST has a network analysis measurement capability to 750 GHz that will be use to verify performance metrics. Applicants are encouraged to propose ways of working with NIST to accomplish not only the measurements required to verify the electrical performance of the deliverables, but also measurements that may help them to quantify the performance of various prototypes.

9.03.05.68-R Ultrafast Optical Detector at 1550 nm

NIST's goal is the development of a compact, inexpensive, and efficient source of guided ultrafast electrical pulses, having frequency components from approximately DC (< 10 MHz) to a significant fraction of 1 THz. Our approach is to create the ultrafast electrical pulses from ultrafast optical pulses. We expect the jitter to be low for various measurement and instrumentation scenarios. Examples of optically excited ultrafast sources include, but are not limited to, photoconductive switches and optical rectification. We prefer the 1550 nm wavelength region because inexpensive and compact component are readily available.

NIST seeks development of ultrafast optical detectors that could be used for creating ultrafast electric pulses. Efficient coupling to a coplanar waveguide (CPW) structure would be advantageous, both to take advantage of recent advances in integrated amplifier technology and for the metrology of such circuits. One possible solution might be the development of a photodiode with integrated CPW contact pads.

For Phase 1, the awardee must innovate a device for creating ultrafast (3 dB electrical bandwidth of 200 GHz or more) electrical pulses and efficiently couple the pulses to a separate CPW fabricated on a separate substrate of a material of their choosing. The resulting pulse on the CPW should have 3 dB corner frequencies at less than 10 MHz on the low end and as high as possible (> 200GHz) on the high end. The device should be designed to be excited by commonly available, mode-locked 1550 nm erbium-doped fiber lasers. The optical to electrical conversion efficiency of the device should be comparable to commercially available photodiodes, i.e., on the order of 0.1 A/W, generating 10 mV peak in a 50 ohm load for a peak optical excitation power of 2 mW. As a minimum demonstration of feasibility, the awardee must deliver to NIST five prototype devices that will be tested on the NIST electro-optic sampling system (see references).

If these specifications are met and if sufficient funding is available, for Phase 2, the awardee must improve the device design in terms of bandwidth, coupling efficiency, and optical responsivity to make it commercially attractive, e.g., for testing high-speed circuits. The awardee must deliver ten refined devices to NIST.

NIST is willing to work collaboratively with the awardee to help with design and evaluation of prototype devices.

References:
[1] D. F. Williams, P. D. Hale, and T. S. Clement, “Calibrated 200 GHz waveform measurement,” IEEE Trans. Microwave Theory Tech., Vol. 53, pp. 1384–1389 (April 2005).

[2] D. F. Williams, P. D. Hale, T. S. Clement, and J. M. Morgan, “Calibrating electro-optic sampling systems,” IMS Conference Digest, pp. 1527–1530 (May 2001).

9.03.06.68-R High-Efficiency Visible Light Photon Counters

To characterize new types of quantum states of light, highly efficient single photon detectors are needed. At NIST, we are interested not only in detecting single photons but also in counting the number of photons in a pulse of light. Visible Light Photon Counters (VLPCs) are a promising technology that could be embedded in systems to obtain very high system-detection efficiency [1]. At present, the technology has not been optimized for very many wavelengths or demonstrated in simple, turnkey systems.

For Phase 1, the awardee must produce and deliver to NIST five prototype detectors that demonstrate both high efficiency (> 85%) in the near IR (telecommunication wavelengths) and photon-number-resolving capability.

If these specifications are met and if sufficient funding is available, for Phase 2, NIST is willing to work collaboratively with the awardee to help measure the performance of the detectors more thoroughly, including, but not limited to, measurements of dark counts, jitter, and maximum count rate. In addition, Phase 2 development should extend the range of operating wavelengths and eliminate any requirement of cryogens for cooling. Other Phase 2 development may include optical packaging for large arrays of devices.

References:
[1] See, e.g., E. Waks, K. Inoue, W. D. Oliver, E. Diamanti, and Y. Yamamoto, “High-Efficiency Photon-Number Detection for Quantum Information Processing,” IEEE Journal of Selected Topics in Quantum Electronics, 9(6), pp. 1502–1511 (Nov./Dec. 2003).

9.04 Information Technology

9.04.01.77-R An Automated Test-Bed for Assessing System-of-System (SoS) Assurance

System of systems (SoS) “is a collection of task-oriented or dedicated systems that pool their resources and capabilities together to obtain a new, more complex, 'meta-system' which offers more functionality and performance than simply the sum of the constituent systems. Currently, systems of systems is a critical research discipline for which frames of reference, thought processes, quantitative analysis, tools, and design methods are incomplete” [1].

Assurance is “a statement or indication that inspires confidence; guarantee” [2]. The terms assurance, confidence, integrity, trust, reliability, dependability, etc., have caused a level of confusion in the software engineering community because of their similarity in spoken meaning. One aspect of this confusion is definitional and a second is “measurability.” For this solicitation topic, NIST is interested in both as applied to a system of systems.

SoS assurance involves: (1) software, (2) the system (hardware) that the software operates in, (3) the incoming data environment that the system operates in, and (4) the threat space that the environment operates in. Further, all of these are a function of the 5-th variable, time, and the 6th dimension, the “ilities”. “Ilities” include emergent, non-functional behaviors such as reliability, security, safety, availability, fault tolerance, performance, dependability, usability, etc.

Of these six dimensions, the “ilities” are the hardest to understand and bound. For example, performance and availability can be numerically measured; safety and security cannot. Further, several of these attributes may conflict, such as security and performance. Therefore to demonstrate that the software of a system can be assured, it requires a combination of qualitative arguments concerning the level achieved for some attributes in combination with the numerical (quantitative) scores measured for others.

This solicitation topic involves the feasibility of developing a new system of systems assurance model during Phase 1. A reasonable set of research questions to address in Phase 1 could include but are not limited to the following issues:

(1) Are “ilities” composable in software, given that software is non-physical? Traditional engineering allows for factors such as decay, wear, and rot. Are those notions appropriate for software-centric systems?

(2) Can we isolate and define the key aspects of the system and the environment (both networked and wireless), and if not, what pieces can we define?

(3) What role if any does history play in predicting future threats?

(4) Are “ilities” measurable, and if so, which ones can be measured and with what levels of confidence?

(5) Are the interfaces between sub-systems the correct level of abstraction to address building a language that enables late-binding of components in a dynamic environment?

(6) What forms of evidence are needed to build the claims and arguments that a SoS is reasonably assured?

If feasibility is successfully shown in Phase 1, and if sufficient funding is available, for Phase 2, the awardee must produce: (1) an automated software testing bed that measure those measurable “ilities” for each subsystem of a SoS, and (2) an automated utility for visually showing the measurements for each “ility” of each subsystem. If successful, the results from Phase 2 should be commercializable after additional research on how to compose the measurements occurs.

NIST staff will be available for consultation and input if needed.

[1] **http://en.wikipedia.org/wiki/System_of_systems**

[2] Second College Edition of the American Heritage Dictionary.

9.04.02.77-R Cloud Computing Security Discriminators

Cloud computing is touted as the platform for next generation IT infrastructure and future software applications. Cloud computing has been defined at NIST as a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction [1]. Five unique characteristics of cloud computing discussed in this working definition (Version 15) are: on-demand self-service, broad network access, resource pooling, rapid elasticity, measured service.

There is significant debate regarding the security and privacy of data in the cloud computing model. Some believe that existing security protection mechanisms that have been developed over the past 30 years are sufficient for protecting sensitive data and other important assets residing within a cloud computing infrastructure. Others believe cloud computing adds new security challenges not seen before. This debate centers fundamentally around whether access control mechanism, application security assurance, network security measures, and data integrity protections, as they exist today, adequately scale and seamlessly coordinate within a massively distributed, shared computational environment like cloud computing.

This SBIR subtopic seeks to explore which security concerns associated with cloud computing are significantly different from those of traditional IT infrastructure and application platforms, i.e., non-cloud computing architectures. Key capabilities of cloud computing infrastructure such as virtualization, shared data store, identify management, and application/data integrity could be examined as part of this analysis, but this topic is not limited to those.

For Phase 1, the awardee will deliver to NIST a written report detailing unique security vulnerabilities and weakness that are specific to cloud computing. These differences will be examined across various cloud computing service and deployment models (Iaas, PaaS, or Saas). Further, an analysis of how to test clouds for these should be included in the Phase 1 report.

If Phase 1 is successful and if sufficient funding is available, for Phase 2, the awardee will develop a prototype security framework that encompasses the critical vulnerabilities and weaknesses identified during Phase 1. This framework will include an automated cloud security prototype tool that enhances existing open source and/or commercial capabilities such as those described in [2] to provide demonstratable cloud security.

NIST staff will be available for consultation and input if needed.

[1] Mell and Grance, “The NIST Definition of Cloud Computing". **http://csrc.nist.gov/groups/SNS/cloud-computing/**. Version 15.0.

[2] Stiehm and Gotimer, “Building Security In Using Continuous Integration”. CrossTalk, April/May 2010.

9.04.03.77-R Ontologies for Modeling Enterprise Level Security Metrics

Currently, it is difficult to answer simple questions such as “are we more secure than yesterday” or “how should we invest our limited security budget.” Decision makers in other areas of business and engineering often use metrics for determining whether a projected return on investment justifies its costs. Spending for new cyber-security measures is such an investment. Therefore, security metrics that can quantify the overall risk in an enterprise system are essential to make sensible decisions in security management.

Information Security is a critical part for any enterprise. Often wrong decisions are made due to insufficient knowledge about the security domain, threats, possible countermeasures and the company’s assets. There are several reasons for this. First, security terminology is not precisely defined, which leads to confusion among the security experts and the customers who should be served. Security ontologies are a viable solution for this problem because they allow a precise definition of the entities and their relationships to each other. Secondly, decisions about security are based on intuition rather than a thorough cost/benefit analysis. The main goal of the ontology is to develop a data model that has knowledge about which threats endanger which assets and which counter measures can reduce the probability of a damage.

Your proposal should include what sort of things that we need to measure for security and how to gather the data to compute the metrics. It should also include a data model using entities and relations for enterprise level security metrics. NIST is willing to work collaboratively with the awardee to help in the design and reference implementation. Phase 1 will demonstrate the feasibility of the design of an ontology for enterprise level security metrics. In Phase 2 a functioning and tested implementation using OWL will be completed.

References:
1. Andrew Jaquith, Security Metrics: Replacing Fear, Uncertainty, and Doubt, Addison Wesley, 2007.

2. A. Singhal and D. Wijesekara, "Ontologies for Modeling Enterprise Level Security Metrics", 6th Annual Cyber Security and Information Intelligence Research Workshop, Oakridge National Labs, Oakridge, April 21-23 2010.

3. W3C (2004) OWL Web Ontology Language Overview. **http://www.w3.org/TR/owl-features**.

4. L. Wang, A. Singhal and S. Jajodia, "An Attack Graph Based Probablistic Security Metrics", In Proceedings of 22nd IFIP WG 11.3 Working Conference on Data and Application Security (DBSEC 2008), London, UK, July 2008.

9.04.04.77-R Monitoring for Complex Information Systems

It is a common practice to monitor the health of mechanical systems by observing their behavior and the state of their environment. Behavioral changes can signal degradation of the system, and unusual environmental conditions can indicate a state of affairs that the system is unprepared to cope with.

A similar approach would be appealing for software systems since they too can exhibit behavioral changes in advance of a failure. Environmental changes are also an important factor in software performance, since such changes invalidate past experience about the software's quality and other of its other "ilities." Furthermore, in a complex software system, actual failures may only become visible in the form of aberrant behavior.

Traditional health-monitoring approaches are hard to apply to computer systems because the traditional approaches deal with numerical measurements from mechanical devices. Computers, on the other hand, generate large amounts of information that could be used for diagnostic purposes but cannot meaningfully be converted to numerical form.

The biggest problem with applying traditional health-monitoring approaches to software systems is that the measurements used for health-monitoring traditionally have to be numbers. The key point is that for mechanical measurements, similar numbers have similar meanings. For example, if a rotating shaft operates reliably at 100 RPM and also at 110 RPM, we can probably assume that it is also reliable at 105 RPM. It is difficult to use traditional health-monitoring techniques for software, because if we monitor software behavior we often get strings or nominal values (nominal values are identifiers of things, such as an IP address, a port number, or the state of a transaction). Even if such values are in numerical form (or if we convert them numbers using some arbitrary scheme), they do not automatically have the property that similar values have similar meanings. This means that traditional health-monitoring techniques often produce meaningless results when applied to such observations.

Recent work in machine learning has resulted in the development of string kernels [1, 2], which provide various similarity measures for strings of symbols. The ability to determine when two strings are similar or dissimilar is the key to adapting traditional health-monitoring techniques for use with software. String kernels have already been used in numerous data-analysis applications, including anomaly detection. The question is whether these approaches can be applied to health monitoring for information systems based on information gathered at the interfaces between software systems.

The goal for Phase 1 is to complete a feasibility study to determine if health-monitoring can be used to distinguish normal software behavior from abnormal behavior using data captured from software system interfaces. The captured data will be assumed to be unencrypted. The goal of the feasibility study will also be to determine whether abnormal behavior can be efficiently distinguished from normal behavior using string kernels. For statistically-based algorithms it is not usually possible to obtain 100% accuracy, especially in a prototype system, so part of the study will be to determine what level of accuracy can be obtained.

The goal for Phase 2 will be to build a prototype system for health-monitoring. This system will be an offline prototype, meaning that it uses previously captured data and runs on a desktop PC. Phase 2 will also evaluate the time-and space efficiency of the proposed approach and ensure that health-monitoring can be automated sufficiently to be used by persons who do not have an in-depth understanding of the underlying technology.

NIST staff will be available for consultation and input if needed.

[1] R. Herbrich. Learning Kernel Classifiers. MIT Press, Cambridge, MA, 2002.

[2] A. Smola. Learning with Kernels. PhD thesis, GMD First, Berlin, Germany, 1998.

9.04.05.77-R Development of a SCAP Content Creation Tool

NIST and its partners have developed the Security Content Automation Protocol (SCAP), a suite of technical specifications for organizing, enumerating, and expressing security-related information in standardized ways. SCAP and associated reference data, can be used for maintaining the security enterprise systems, such as automatically verifying the installation of patches, checking system security configuration settings and examining systems for signs of compromise.

The ability to achieve and sustain security automation using SCAP is contingent upon the ability to create and maintain content for a wide range of products and platforms. In the absence of a full-featured SCAP editor, creation and maintenance of SCAP data streams is difficult and time-consuming. IT security practitioners often possess the requisite IT security domain expertise for crafting security guidance but generally are not knowledgeable in the creation of well-formed SCAP content.

This SBIR solicitation is to design and develop an editing tool with a user interface that hides the underlying SCAP data formats and presents automated security content using a look and feel familiar to IT security practitioners (e.g., system administrators, security officers). Through the development of an SCAP editor we seek to foster the creation of additional automated security content; impart greater efficiency in the content creation process; and remove the requirement to learn the SCAP data formats in order to generate new automated security content.

For Phase 1, the awardee will deliver to NIST a horizontal prototype that includes screen mockups, identifies available functionality, and includes all menus, dialog boxes and toolbars that will be presented to the user.

If Phase 1 is successful and if sufficient funding is available, for Phase 2, the awardee will develop a functional prototype that implements a subset of capabilities deemed to have the broadest utility (i.e., those features used across numerous security benchmarks) that allow IT security practitioners to create well-formed SCAP content.

NIST staff will be available for consultation and input if needed on a limited basis.

9.05 Manufacturing

9.05.01.73-R Sustainable Manufacturing Maturity Model Development

To objectively evaluate progress towards their sustainable manufacturing (SM) goals, companies need new tools to effectively plan for the near, intermediate and long-term. These SM goals address issues such as energy efficiency, renewable energy use, emissions and toxic material reduction, waste elimination, process analysis and optimization methods, standards and regulatory requirements. An evolving SM maturity model (SMMM) that includes a set of performance indicators that can be quantifiably measured with derived uncertainties can facilitate effective planning while supporting conformance to regulatory and standards requirements. The SMMM is envisioned to help companies prioritize activities and track progression within the enterprise towards the goal of becoming sustainable.

Driven by the guiding principles of SM, SMMM will further promote the integration of traditionally separate organizational functions, set process improvement goals and priorities, provide guidance for quality processes, and provide a point of reference for appraising sustainability in current manufacturing processes. The work from this solicitation will help identify, understand, and report on:

- complex intertwined issues
- statistical and analytical methods
- measurement principles to allow reporting/conformance to standards
- requirements to support sustainable planning
- product – process integration
- new technologies, methods, and processes with ability to evaluate performance
- continuous improvement

This SBIR solicitation is an initial step in the development of a tool that uses identified data and defined analysis procedures to support functionality described in the preceding paragraph.

A successful Phase 1 submitter would deliver to NIST:

- Initial specifications and requirements for SMMM development, and
- Case study demonstration that illustrates its functionality and capability for enabling or measuring SM maturity level.

The awardee will work with NIST staff members involved in sustainable manufacturing R&D to develop requirements for evaluating the SMMM functionality and performance against industry needs.

A successful Phase 2 submitter would deliver to NIST:

- SMMM that adhere to best practices and guidance from relevant maturity models, ISO 14000, relevant standards and regulations as appropriate.
- Tool that demonstrates SMMM and supports continuous improvement through key performance indicators.
- Information acquisition coordinated with life cycle data for use at different maturity levels.
- Case studies that demonstrate open exchange of information with SMMM.

9.05.02.73-R Decision Support Tools for Sustainable Manufacturing

In order to include total lifecycle synthesis and sustainability in to the early design stage of products we need to develop appropriate information infrastructure, and tools. Design and manufacturing integration issues have been long studied to understand how to include manufacturing issues in the early design stage. However, this integration was traditionally focused heavily on engineering issues. Sustainable Manufacturing, a systems approach for the creation and distribution (supply chain) of innovative products and services, is now being termed as “business megatrends” and getting a wider attention. In order to do “what-if” analysis and synthesis in the early design phase it is critical to integrate environmental aspects into product design and development, product lifecycle management and total lifecycle analysis. This SBIR solicitation seeks development of a tool that uses identified data and defined analysis and synthesis procedures to support interoperability among design engineering tools (such as CAD, PDM, PLM), engineering and manufacturing analysis tools (such as CAE, CAM) and LCA tools. Such a tool should support energy and material monitoring, recyclability and reuse analysis, as well as other methods to optimize the design and minimize the impact of a product and process on the environment.

The awardee will work with NIST staff members involved in sustainable manufacturing R&D to develop requirements for lifecycle assessment (LCA) tools to calculate GHG (green house gases, including CO2) footprints and integrate with design tools.

A successful Phase 1 submitter would deliver to NIST:

Requirement analysis and data exchange models to integrate maintenance, repair operations (MRO) and to compute environmental impacts of product design and development, using standards such as PLCS-ISO 10303-239 (product lifecycle support).

Extensions to the traditional engineering analysis methods, such as, space discretization approaches (Finite Element Method (FEM), mesh less, Structured grid based analysis-Extended FEM) and time discretization approaches (CFD-computational fluid dynamics) to include sustainability factors, such as, energy, material minimization, toxicity reduction, carbon footprint minimization etc.

- Proof of concept case study to demonstrate the integration of design tools with engineering analysis tools for design optimization for sustainability.

A successful Phase 2 submitter would deliver to NIST:

- Develop necessary standards based application programming interfaces (APIs) between design tools, engineering analysis tools, and LCA tools.

- Maximize the application of available standards such as STEP (ISO 10303-xxx), ISO 14000 and relevant standards and regulations.

- Develop service oriented architecture based solution for such integration.

- Enable open standards for interfacing design tools, engineering analysis tools, and LCA tools.

9.05.03.73-R Disassembly Model and Analysis Tools for End-of-Service Life Product Treatment

Disassembly has become an important link for treating End-Of-Service-Life (EOSL) mechanical products. An example on the development of a disassembly information model is available [1]. Software tools for analyzing the disassembleability of EOSL products are necessary so that disassembly factory can develop appropriate process plan to separate useful parts with disposal parts. This will help reuse, remanufacturing, and recycle used products to reduce environmental impacts from solid wastes.

This SBIR solicitation seeks development of model and analysis tools for disassembly. A model will enable implementers to create analysis software. Analytical capability enables remanufacturing and recycling companies to more effectively treat used products. A successful Phase 1 submitter would deliver to NIST:

- An information model of disassembly
- Case studies of disassembling products
- Prototype of an analysis software toolset
- A detailed project plan for developing software tools

For Phase 2, deliverables should include:

- A set of integrated software tools that will evaluate disassembleability of a product design, generation of disassembly sequence, and disassembly process plan
- A suite of cases that are used to test the software
- Software documentation

The awardee can work with NIST staff members who are involved in sustainable manufacturing and disassembly.

[1] Feng, S., Lee, H., Joung, C., and Ghodous, P., "Development Overview of an Information Model for Disassembly," the Proceedings of the 7th Global Conference on Sustainable Manufacturing, Chennai, Tamil Nadu, India, December 2009, pp. 295 – 300.

9.05.04.73-R Sustainability Performance Analysis Tools for Evaluating Manufacturing Processes

Sustainable indicators and metrics provide the measurement foundation to evaluate the performance of manufacturing processes. Many sustainable indicators and metrics have been published by the Global Reporting Initiative [1] as well as some others, such as Dow Jones Sustainability Index [2]. Specific indicators and metrics for evaluating the sustainability performance for manufacturing processes are rarely available. Software tools for analyzing the sustainability of a given manufacturing are necessary so that factory management can identify problem areas in a process. This identification is important to managers to make necessary changes or improvements to achieve performance goals in sustainability.

This SBIR solicitation seeks development of tools implementing publically available indicators that are relevant to manufacturing and identify any missing indicators that are necessary to be included, and implement those too. Analytical capability enables manufacturing companies to benchmark current performance against companies goals or regulations, track performance in time, and identify problems.

A successful Phase 1 submitter would deliver to NIST:

- A set of indicators used to evaluate sustainability performance in manufacturing processes
- A set of benchmark metrics corresponding to the above mentioned indicators
- Prototype of an analysis software toolset
- A detailed project plan for developing software tools

For Phase 2, deliverables should include:

- A set of integrated software tools that will evaluate sustainability of manufacturing based on sustainability indicators
- A suite of cases that are used to test the software
- Software documentation

The awardee can work with NIST staff members who are involved in sustainable manufacturing measurement and testing to develop requirements for performance analyses.

1. **http://globalreporting.org**

2. **http://www.sustainability-index.com**

9.05.05.73-R Standard OWL Reasoning Support for Physical Quantities and Units

The OWL Web Ontology Language [1] is emerging as an important tool to enable manufacturing enterprises to manage their information intensive activities such as product design for sustainability, supply chain planning, and systems and information integration. What OWL brings to this environment is the ability to capture knowledge in a precise way that then can be reasoned over by software systems. This reasoning can support merging of data and detection of inconsistencies among other capabilities. Previous NIST supported work has enhanced these capabilities by providing an additional formal interpretation and associated tooling that extends OWL such that it can be used as a schema language. Thus OWL is now a nearly complete tool for model driven integration.

However, for use in technical domains and for eBusiness environments it still has some weaknesses. Values describing physical quantities such as length or electric current are key elements of data in these domains. Physical quantity values are associated with aspects of things or phenomena, and logically contain both a numerical component and a unit (although the unit may be implicit or assumed). Physical quantities can be represented using many different units yet indicate the same value, and machine reasoning is needed to properly recognize when these values are the same, inconsistent, or out of range. Currently OWL has only basic support for expressing and reasoning over plain numerical values and no means to operate on physical quantity values with unit components. While there are ways to work around this, to be useful for manufacturing applications, these ways need to be standardized and support reasoning such as simple forms of dimensional analysis. There have been various models proposed for handling units in OWL, but none have any widespread use or generally available reasoning support. Without a full and explicit handling of units in OWL, OWL based reasoning will not fully understand technical data used in product design or supply chain planning and management. This may lead to missed opportunities, from lack of recognition of compatible values, or it may lead to disaster due to lack of recognition of different or incompatible values.

This subtopic seeks a model for units and measures for OWL that:

- supports physical quantities such as length, electric current, luminous intensity, etc. as supported by SI [2, 3],

- is largely consistent the International Vocabulary for Measurement – VIM [4],

- can support all units and quantities in SI,

- can support additional units and quantities needed for commerce, including alternative unit systems, counts, mixtures of counts and quantities, and ratios, and

- maintains information about quantity kinds in ratios and other quantities despite the dimension vector (e.g. torque and work must be distinguishable).

The standard model must also be accompanied by software capable of machine reasoning that extends OWL description logic reasoning and supports:

• the detection of inappropriate comparison of quantity kinds,

• detection of incompatible use of quantity kinds in the model (as in subsumption relationships or OWL domain or range constraints),

• correct interpretation of sets of quantity values with different numerical values, but with units of measure such that they represent the same values (e.g. 2.54 CM and 1 inch) [5] to work with OWL cardinality restrictions (A.K.A. number restrictions) and

• that supports a data range extension for OWL such as the OWL 2 Data Range Extension: Linear Equations **http://www.w3.org/TR/2009/WD-owl2-dr-linear-20090611/**.

Some of the issues and a suggested approach for quantities and units in OWL are discussed in a paper at the OWLED 2008 workshop entitled “Quantities in OWL” by Bijan Parsia and Michael Smith [6] that respondents may fine helpful.

Note that this subtopic is challenging, perhaps more challenging than it appears from the above description. For example, while SI is clearly the model for units around which there is international agreement, it is an inadequate basis for the machine reasoning that this subtopic requests. Two examples of its shortcomings are:

• no explicit support for a count type

• unit/quantity dimension vectors do not uniquely identify a kind of quantity

Thus SI support is a necessary requirement, but its model is not sufficient to meet the goals of this subtopic. ISO 80000 [7] may enhance the standard system of quantities to address these needs. The ideal proposal for this subtopic would investigate emerging approaches in addressing these problems, and choose or develop a model that supports SI while also providing full specification of quantity kinds and of count quantities to support the machine reasoning capabilities specified in this subtopic.

NIST hopes that the OWL representational extension and machine reasoning capability resulting from this subtopic could be the basis for supporting both ideal and measured values in OWL. Ideal values are used to specify a desired characteristic of a product or service and may include tolerance information. Measured values are the result of some measurement and often include uncertainty information as well as other metadata that may describe the measurement procedure, apparatus, temperature, time, or other information that would help with interpretation of the measurement value. While this subtopic does not request support for metadata associated with these types, an ideal response would demonstrate consideration of how extensions to the proposed solution may support these value types in the future.

We have highlighted only some of the challenges implicit in this subtopic. The ideal submission is likely to result from submitter knowledge of OWL and machine reasoning, as well as quantities, units, scales and measures.

A successful Phase 1 submitter would deliver to NIST:

- a specification of an extension to OWL and/or the OWL model used to support physical quantities, units, and quantity values as described above,

- a paper explaining the extension, it's means of extensibility, and any issues expected in tool implementation to support reasoning over quantity types and quantity values, and

- a proof of concept implementation of quantities with units reasoning that works with existing or emerging OWL reasoners such as Pellet or Hermit.

A successful Phase 2 submitter would deliver to NIST:

- a specification for an extension to OWL that adds the expressivity and reasoning support for quantities, units, and quantity values described above that is sufficiently complete to be used as the basis for a future revision of OWL,

- a robust beta version of the quantities and units reasoning implementation integrated with one or more of the popular OWL reasoners.

NIST staff will be available for consultation and input if needed.

1. **http://www.w3.org/TR/owl-ref/**

2. International System of Units, SI Units **http://www.bipm.org/en/si/si_brochure/**

3. The International System of Units (SI), NIST Special Publication 330, 2008 Edition Barry N. Taylor and Ambler Thompson, Editors
http://physics.nist.gov/Pubs/SP330/contents.html

4. International Vocabulary of Metrology, VIM (3rd ed, 2008)
http://www.bipm.org/en/publications/guides/vim.html

5. Note that this capability requires unit conversion across systems of units, and not merely within a system of units.

6. **http://www.webont.org/owled/2008/papers/owled2008eu_submission_34.pdf**

7. ISO 80000-1:2009, Quantities and units – Part 1: General.

9.05.06.68-TT Calibration of Critical Dimension Scanning Electron Microscopes

Manufacturers of semiconductor integrated circuits use critical dimension scanning electron microscopes (CD-SEMs) to measure the dimensions of their smallest printed features (e.g., transistor gate sizes and lithography assist features) to insure that the manufactured product conforms to the design. The smallest features for advanced processes are less than 30 nm, and the desired uncertainties are of the order of 1 nm. At this scale, measurement errors due to the spread of the electron beam within the sample are significant. These errors are particularly important for feature-width measurements, and the errors vary depending upon the sample composition, shapes of edges, their immediate neighborhood (e.g., proximity of neighboring features), and instrument conditions (e.g., beam size and beam energy).

NIST has developed methods for simulating scanning electron microscope (SEM) secondary electron images of samples with complex 3-dimensional shapes [1,2]. The simulator calculates an image given a sample and instrument parameters. A model-based library method [3] allows the simulations to be "inverted" in order to determine the sample geometry given its image.

We seek proposals to produce a commercial width-measurement calibration system for CD-SEMs by combining the above NIST measurement technology and suitable calibration samples, designed for use by an industrial metrology engineer who is not either a modeling or software expert. The calibration system should account for all instrument properties relevant for the measurement, including magnification, beam size, and field distortion. Innovative research is likely to be required for sample design and fabrication, system validation, and potentially for modeling adjustments.

Phase 1 deliverables must include the production (with a copy for NIST) of integrated software to perform a model-based width measurement using the NIST dielectric function theory approach, and the fabrication of a prototype set of samples to be used for calibrations. If Phase 1 is successful and if sufficient funding is available, for Phase 2, the project would produce and validate a commercial calibration system for CD-SEM width measurements, with updated software and a calibration sample set for NIST.

NIST staff will be available for consultation and input if needed.

References:
[1] J. S. Villarrubia, N. W. M. Ritchie, and J. R. Lowney, "Monte Carlo modeling of secondary electron imaging in three dimensions," Proc. SPIE 6518, 65180K (2007).

[2] J. S. Villarrubia and Z. J. Ding, "Sensitivity of scanning electron microscope width measurements to model assumptions," J. Micro/Nanolith. MEMS MOEMS 8, 033003 (2009).

[3] J. S. Villarrubia, A. E. Vladar, and M. T. Postek, "Scanning electron microscope

dimensional metrology using a model-based library," Surf. Interface Anal. 37, 951–958 (2005)**.**

9.05.07.68-R A Common Platform for Microrobotics Research

NIST is developing untethered MEMS devices, also referred to as microrobots. These MEMS-scale microrobots have dimensions of 100's of micrometers (not more than 600 micrometers in the largest dimension) and nanogram masses. These microrobots operate by wireless power and control signals from externally applied electrostatic or electromagnetic fields. They are fabricated using highly customized MEMS processes to create intended stress and/or electromagnetic characteristics in the materials.

This NIST research has two goals: developing the potential of this nascent technology, and using lessons learned to develop solutions for a range of other MEMS metrology needs. In parallel with these internal goals, NIST has organized international competitions of university-based microrobotics researchers so that all might share their research achievements.

At the present time, no commercial MEMS foundry process can be used to completely fabricate microrobots. Final production processing is required at a research facility, such as NIST's Center for Nanoscale Science and Technology. Each research group in the field typically develops their own production process. These development efforts are time consuming and often not transportable between different laboratories. The resulting processes are often highly specialized and applicable to only a single type of microrobot.

The present solicitation is for the development of a commercial process that could be used for complete production of microrobots on a common and broadly useful platform. The goal is to enable batch production of microrobotic devices designed by many laboratories, on a multiproject-wafer basis, without overly restrictive design rules. Success of this SBIR project would put the awardee in the position to serve a role in the microrobotics community similar to the role that MOSIS (**http://www.mosis.com/**) plays for the CMOS community, serving as a virtual microrobotics foundry with well-defined processes and design rules. Through our outreach activities we have observed that there are a number of universities that would like to enter this nascent field, but which lack the processing expertise and/or tools. This project would overcome that obstacle.

In Phase 1 an awardee must identify a MEMS foundry (or foundries) capable of full-line fabrication of MEMS-scale microrobots, deliver a microrobot fabrication process flow specification including preliminary design rules and identifying the source of each process step, and provide a proof-of-concept demonstration of functional electrostatic and electromagnetic microrobots produced by this process.

In Phase 2 the awardee would demonstrate multiple types of functional, standard platform microrobots using current “best-in-class” processing technology. These technologies will include the electrostatic and electromagnetic technologies demonstrated in Phase 1; the additional type(s) will be at the discretion of the awardee. Successful demonstration will include any needed substrate or operating environment. The awardee would also deliver final microrobot and operating environment design rules and process specification in a form that can be immediately used by NIST and other research organizations.

NIST staff will be available to assist the awardee in identifying key process steps needed to successfully fabricate the different classes of microrobot. We will be available to answer questions about the state-of-the-art in MEMS robotic fabrication and answer questions about the additional process steps needed to produce MEMS robots on a MEMS foundry.

Reference:

[1] J.J. Gorman, C.D. McGray, and R.A. Allen, “Mobile Microrobot Characterization through Performance-Based Competitions,” Proc. PerMIS’09, September 21–23, 2009, Gaithersburg, MD, USA. ACM 978-1-60558-747-9/09/09, and references therein. Available on-line at:
http://www.nist.gov/customcf/get_pdf.cfm?pub_id=904187

9.05.08.68-TT Production of ISMRM/NIST MRI Calibration Phantoms

NIST, in conjunction with the International Society for Magnetic Resonance in Medicine (ISMRM), has designed a magnetic resonance imaging (MRI) system phantom. A phantom is an inanimate structure used to calibrate and test MRI scanners and their operating protocols. The system phantom consists of a 200 mm plastic sphere of water enclosing 57 fiducial spheres and 42 contrast spheres. Also included in the phantom is a resolution inset and slice profile wedges. The detailed structure of the phantom and the uses of the phantom are documented at the publically accessible NIST TWIKI site **http://collaborate.nist.gov/twiki-div818/bin/view/Div818/PhantomDevelopment**. Two initial system phantoms have been built and are currently being imaged at biomedical imaging sites across the country under the guidance of the ISMRM Ad Hoc committee on Standards for Quantitative Magnetic Resonance (SQMR).

The present solicitation is for the further development and ultimate commercialization of system phantoms based on this design. The awardee would develop methods to manufacture the ISMRM system phantom in a cost effective manner, with high levels of quality control, and with measurement traceability (to NIST) in both physical dimension and electromagnetic properties. The targeted lifetime of the system phantom (the period over which the phantom properties are guaranteed to meet the published specifications) is five years, and NIST intends to validate the lifetime through long-term monitoring of parameter stability. Proposals should include an analysis resulting in an estimate of what the cost of such a phantom would be when commercialized, as our goal is to have the price be sufficiently low that imaging centers would voluntarily purchase such system phantoms for quality control. We note that there are about 10,000 MRI scanners in use in the U.S. currently and that the phantoms would be replaced after five years.

In Phase 1 the awardee must design a manufacturing process to meet a specific price goal. This entails developing the required molds and filling/sealing equipment, as well as the quality system for ensuring measurement traceability of all key parameters. Of particular note is the method to automatically or semi-automatically fill and seal the contrast and fiducial spheres. They must be of high quality without defects, air bubbles, or leaks that would cause imaging artifacts and long-term instability. At the conclusion of Phase 1, two prototype phantoms made using the proposed manufacturing process must be delivered to NIST for evaluation.

If Phase 1 is successful and if sufficient funding is available, for Phase 2, the awardee must complete implementation of the manufacturing process and quality system to ensure measurement traceability. The awardee must manufacture and deliver to NIST 50 MRI system phantoms that would be distributed to imaging centers for research and testing. During Phase 2, the awardee would be expected to work cooperatively with NIST and the ISMRM SQRM committee to validate protocols using the phantoms to improve the consistency and quality of MRI imaging. This may result in changes to the design of the phantoms.

NIST is willing to work collaboratively with the awardee to help design the process for ensuring measurement traceability of the key elements of the phantom. This includes measurement of the “T1” and “T2” relaxation time constants of the materials used.

9.05.09.73-R RFID-Integrated Sensor Networks

Background:
Radio Frequency Identification (RFID) technologies are rapidly emerging as a means for tracking products and assets. Sensors can provide information about the condition of the products. Combining these two technologies will create new business opportunities, such as for tracking manufactured products throughout their life cycles or tracking perishable consumer goods in a supply chain. The IEEE 1451.7 standard [1] was developed to provide methods for interfacing transducers (sensors or actuators) to RFID systems, and for reporting transducer data within the RFID systems and IEEE 1451 infrastructure.

Scope:
Innovations are sought to integrate RFID systems with networked sensor systems based on the IEEE 1451.7 standard in an economic manner. The IEEE 1451.7 standard provides a command set for accessing IEEE 1451.7 transducer data and parameters, such as the transducer electronic data sheet (TEDS) and timestamp

information, but does not dictate use of a particular air interface format. Proposals submitted under this subtopic may address access to or cooperation with NIST staff. NIST is willing to work collaboratively with the awardee(s) to help with the evaluation of operating parameters, but will not be involved in the system design.

A successful Phase 1 awardee should deliver to NIST a prototype (for demonstrating feasibility) of an IEEE 1451.7 RFID-integrated wireless sensor network consisting of at least one network capable application processor (NCAP) with a separate or integrated transducer interface module (TIM) (see Appendix D of Reference 1) and at least two IEEE 1451.7 transducers (with at least two sensors each, e.g., temperature and vibration). The NCAP should provide an Ethernet network interface for sensor access via a personal computer and a radio-frequency (RF) unit for super high frequency (SHF) (2.4 GHz) RFID frequency band to communicate with the IEEE 1451.7 transducers. A partial list of standardized commands that must be supported for the feasibility demonstration include: (1) Read-Sensor-Identifier, (2) Read-Primary-Characteristics-TEDS, (3) Write-Sample-And-Configuration, (4) Read-Sample-And-Configuration, and (5) Read-Single-Memory-Record, as defined in the IEEE 1451.7 standard. Each IEEE 1451.7 transducer must include a compatible RF unit, a microprocessor-based command interpreter, memory for the TEDS data accessed by the required commands, two sensors, and the means to digitize the sensor output with at least 8-bit resolution. Fully licensed Windows-compatible software and source code for the demonstration of all required capabilities must also be delivered for NIST use.

A successful Phase 2 awardee would deliver to NIST a full-function prototype IEEE 1451.7 RFID-integrated wireless sensor network with two NCAPs and two IEEE 1451.7 transducers for each NCAP, along with software and source code for demonstration of all required capabilities in the standards.

Motivation:
RFID is rapidly emerging as a means for tracking products and assets. RFID standards are being developed to address these needs. Sensors can provide information about the condition of the products. There is a need to provide sensor data as part of the supply chain reporting. Therefore combining RFID systems with wireless sensor networks will not only identify products, but also determine the conditions and health of the products for condition monitoring and public safety. Development of the requested innovations will advance the state of RFID-integrated sensor systems and will also help accelerate the implementation and application of the IEEE 1451.7 standard to enhance public safety.

Reference:
1. IEEE Std 1451.7-2010 - Standard for a Smart Transducer Interface for Sensors and Actuators - Transducers to Radio Frequency Identification (RFID) Systems Communication Protocols and Transducer Electronic Data Sheet Formats (available from the **http://ieeexplore.ieee.org/xpl/standards.jsp**).

9.05.10.73-TT Semi-Autonomous, Articulated Forklift (SAAF) in Close Proximity to Workers

** This subtopic requires that a license **application** be submitted in conjunction with the proposal. Be sure to include one, signed copy along with the proposal package.*

The NIST HLPR Chair [1, 2, 3] was developed based on forklift technology. The HLPR Chair included a unique articulation design allowing “lift-from-above” patient transfer, positioning, and mobility. Replacing the chair with the original forks or a gripper, HLPR provides much more than a forklift with load: accessibility, acquisition, rotation, measurement and transport capabilities of boxes and other heavy (up to 250 Lbs.) and bulky loads. HLPR, built using a manual forklift frame with added rear drive and steer, and wheel encoders, can be manually or computer controlled. Typically in manufacturing and distribution facilities, humans inefficiently or unsafely access, lift, maneuver and carry boxes, bags, and other loads causing worker injuries similar to patient lift and maneuverability by healthcare workers. Manual and powered lift devices and carts are available but, require humans to awkwardly maneuver loads throughout facilities. Workers knowledge and load accessibility are required to keep material handling costs down, although these operations could be safer and more efficient with intelligent, robotic worker-assistance. Therefore, lacking is a crossover between manually-controlled, powered forklift technology (improved with sizing comparable to humans and forks/gripper articulation for better load access) and automated guided vehicle technology with safe vehicle use around humans and in unstructured environments. Hence, a Semi-Autonomous, Articulated Forklift (SAAF) is needed. Manually accessing a load and then autonomously sending the load to another worker, equipment rack, truck or other area would eliminate many inefficient worker activities and reduce worker injuries if the vehicle can be made safe between loading and unloading areas. Also lacking is perception of the environment required for semi-autonomous vehicle technology to be used around humans. Manually-controlled forklifts are notorious for being unsafe since forklift framing and loads block driver views putting both the driver and pedestrians at risk [4]. 3D LIDAR (light detection and ranging) sensors are becoming useful for measuring volumes in tanks. These sensors also have potential for vehicle application although they have not been integrated and tested on forklift or other industrial vehicles. Similarly, ceiling- or wall-mounted absolute position measurement technology is new and untested on semi-autonomous vehicle technology. Therefore, research that is needed to advance SAAF toward the marketplace includes:

• Applying HLPR to access box, bag or palletized loads from + 90º to - 90º of the HLPR front while lifting/stacking loads from/onto shelves (articulation of forks or gripper) and supporting the load for safe, autonomous mobility.

• 3D measurement of humans, equipment, and overhanging obstacles in the vehicle path integrated with SAAF.

• Model based 3D recognition of doorways (human passageways and truck doors) and other path attributes for safe, efficient vehicle navigation.

- Point-to-point, load transfer around humans and through unstructured environments with knowledge of absolute vehicle position for navigation and tracking.

- Semi-autonomous control using developed open-source NIST control technology advanced with changes from manual to autonomous modes allowing human/robot intervention.

NIST is willing to work collaboratively with the awardee to help with evaluation of the operating parameters, but will not be involved in actual software development and vehicle testing. The awardee(s) will work closely with NIST staff members who are developing manufacturing vehicle standards by providing consultation, drawings, and prototype assistance with background knowledge of the device. Prototype modifications are to be made by the awardee.

Phase 1 will include design and demonstration of interchangeable and articulated forks and box gripper with robust load measurement ready for integration into the SAAF computer control system; design of the SAAF vehicle control code using MOAST ready to accept: absolute positioning sensor (APS) inputs, obstacle detection inputs from a 3D LIDAR sensor, and reactive vehicle control based on APS and 3D LIDAR inputs including; vehicle stop, modify vehicle path.

In Phase 2, a functioning SAAF, using HLPR 1, will be delivered to NIST for its retention and ownership, including:

- a manually-controlled, powered, load measured, articulated pallet, box, bag lift and carry system with onboard, integrated vacuum gripper,

- fully functional SAAF vehicle control code using MOAST including:

    -sensor processing using wheel encoders, steering potentiometer, absolute positioning sensor (APS), and obstacle detection inputs from a 3D LIDAR sensor, model based door frame point cloud processing.

    -world modeling showing path traveled and vehicle tracking, model based door frame recognition.

    -behavior generation reacting to input commands (e.g., go to loading dock or low bay) and processing world models to control SAAF to carry an onboard load or unloaded vehicle from one end of the building to another and dock with a shelf while adapting to humans in and along the path to apply: vehicle stop, modify vehicle path, and/or drive slow. Reacts to door frames as obstacles rotating to the right or left as needed to pass through.

Example plan execution will be as follows:

- Worker A loads SAAF with boxes using onboard vacuum gripper and secures load to the vehicle; commands vehicle with a pushbutton command to carry load to the loading dock from current robot testbed position.

- SAAF traverses out of robot testbed, down the hallways making turns as needed and stopping or avoiding humans, overhanging obstacles or other obstacles along the way to the loading dock.

- SAAF stops at the loading dock, is unloaded by Worker B onto shelfs or in a truck; worker B commands through a pushbutton to return the SAAF back to worker A.

Phase 2 Demonstration will occur at NIST in the Shops Building between the robot testbed and the loading dock.

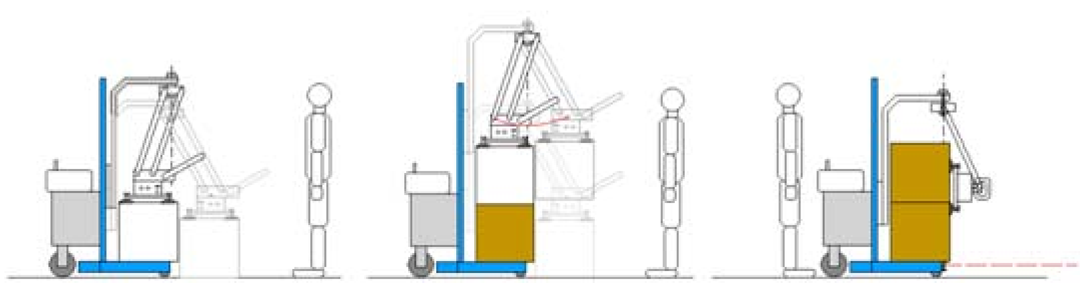

Figure 1 – Concept for box loading (left and middle) onto the SAAP and then (right) sending the vehicle on its way to another location. Only 2D LADAR is shown (red dotted line).

References:

[1] Home Lift, Position and Rehabilitation (HLPR) Chair (patent pending) , filed January 2009.

[2] “Static and Dynamic Stability Measurements of the Home Lift, Position and Rehabilitation (HLPR) Chair/Forklift,” Joshua Johnson, Roger Bostelman, NISTIR, October 2009.

[3] Multiple HLPR Chair publications, 2004 - 2009.

[4] White Paper – “Towards Improved Forklift Safety,” Roger Bostelman, PerMIS 09, October 2009.

* US Patent Application #20090144895, Home Lift Position and Rehabilitation (HLPR) Apparatus **http://appft.uspto.gov/netacgi/nph-Parser?Sect1=PTO2&Sect2=HITOFF&p=1&u=%2Fnetahtml%2FPTO%2Fsearchadv.html&r=1&f=G&l=50&d=PG01&S1=20090144895&OS=20090144895&RS=20090144895**

9.05.11.73-R Dynamic Six Degree of Freedom (6DOF) Vision System

Automated assembly systems in factories typically measure the pose of an object only in highly constrained situations, such as when parts move at a fixed speed in a rigid conveyance, or by stopping an assembly line to sense the position of the part. Next generation flexible and reconfigurable automation processes will remove these constraints using sensor technology that can perceive the position of an arbitrary part under unconstrained motion to either inspect the part or direct a robot to manipulate it while still in motion. This advanced, dynamic six degree of freedom pose sensing technology will promote flexibility and cost savings by replacing expensive fixed installations with more intelligent combinations of sensing and automation, and enable human operators to work and collaborate in close proximity to robots using validated 6DOF sensing. The technology will enable US manufacturers to compete more effectively with foreign firms where greater investments have been made recently in robotic technology.

The goal of this SBIR topic is to build a robust 6DOF parts/object measurement system for next generation agile manufacturing. The system must: 1) self-calibrate when combined with a robot arm or an arm attached to a rail (i.e., 7 DOF arm and rail) or when disconnected from the robot; 2) continuously measure the 6DOF location and orientation of an unconstrained moving object; and 3) report location and orientation for use by a supervisory level computer used to send high level commands to work cell factory equipment such as a robot arm, an automated vehicle, and conveyers. Part location and orientation information must be in the form of x, y, z, roll, pitch, yaw parameters or an equivalent representation suitable for locating the part in the larger workspace.

Phase 1 deliverables will include a detailed document describing the proposed approach to each of the steps above, together with results of experiments for each subcomponent providing evidence that the approach is feasible. NIST researchers will be available to work with the awardee(s), and NIST will make laboratory and measurement facilities available to support this work.

Phase 2 deliverables will include a prototype system that carries out the dynamic 6DOF measurements in unstructured environments, ready for testing at NIST facilities.

9.06 Materials Science

9.06.01.73-TT Environmental Chambers for an Integrating Sphere-based Weathering Device

** This subtopic requires that a license **application** be submitted in conjunction with the proposal. Be sure to include one, signed copy along with the proposal package.*

NIST has developed a unique ultraviolet (UV) weathering device called the SPHERE (Simulated Photodegradation via High Energy Radiant Emission) that is used to accelerate the degradation of polymeric materials. The NIST SPHERE is the only device capable of generating data with requisite precision to quantitatively link field and laboratory weathering results for service life prediction of polymeric materials. It is based on a 2 m diameter integrating sphere and provides a source of high intensity (≈ 22 suns), highly uniform (≥ 95 %), collimated UV radiation for accelerated weathering experiments on a wide variety of polymeric materials such as coatings, sealants, composites, roofing and siding components. In addition to weathering of polymeric materials, such a device could also find extensive use in any photogenic application including agriculture (e.g., the effect of ultraviolet radiation on the growth of fungi), biological (e.g., photosynthesis), or medical (e.g., sunscreen efficiency, skin cancer). Attached to the SPHERE are 28 specimen chambers, in which temperature and relative humidity can be independently and precisely controlled over a wide range and over long exposure periods. Four additional chambers also are equipped with the additional capability of mechanical loading.

The SPHERE environmental chambers were custom-designed and fabricated in-house with very few off-the-shelf components. Phase 1 proposers should address the development of a compact, cost-effective version of the SPHERE environmental chambers that can be commercialized and utilized with an integrating sphere, making use of commercially available components where possible. The chamber should have the capability of maintaining temperature between room temperature and 85 ^{o}C, ± 1.0 ^{o}C,, and relative humidity between between ≅ 0 % RH and 90 % RH, ± 2% RH. The primary Phase 1 deliverable will be a detailed design (executed in a 3D CAD package such as Solidworks) of a commercially viable environmental chamber composed of as many commercially available components as possible, that is compatible with an integrating sphere-based weathering device.

NIST will make available to the awardee detailed information on the designs of the environmental chambers currently used on the full-size SPHERE. The references given below contain a description of the SPHERE and the currently-used environmental chambers. It is expected that a Phase 2 effort will result in the construction and demonstration of a full-function environmental chamber for use on the SPHERE that is suitable for commercialization that can be widely implemented in industry for artificial weathering studies.

References:
* U.S. Patent 6,626,052, “Method and Apparatus for Artificial Weathering”, Jonathan Martin and Joannie Chin, Sept. 30, 2003.

Chin, J., Byrd, E., Embree, N., Garver, J., Dickens, B., Finn, T., and Martin, J., Review of Scientific Instruments, 75(11), 4951-4959, 2004.

Chin, J., Nguyen, T., Gu, X., Byrd, E., and Martin, J., JCT Coatings Tech, Feb. 2006, pp. 2-8.

9.06.02.63-R High-Accuracy Relative Angle Monitoring Apparatus

Many materials characterization methods use the phenomena of diffraction to characterize small distances by measuring small angles and exploiting the wave nature of electromagnetic radiation. In experiments that use monochromatic light as the source probe, the wavelength is often adjusted using paired diffracting crystals for "X-ray light" or diffraction gratings / refraction prisms for "visible light". This wavelength filtering apparatus is referred to as a monochromator. In both cases, the wavelength of the X-ray light is controlled through an angular motion. Correspondingly, the uncertainty in the wavelength is a function in the uncertainty in relative angle between the two diffracting or refracting elements. For metrology purposes this problem is usually addressed by adhering the diffracting crystals to a common reference plane using epoxy or other monolithic architecture. However, in many systems, it is desirable to keep the relative angle variable, requiring the constant monitoring of any angular deviation between the optical elements.

For a general treatment, monitoring the relative angular deviations between the two rotation axes (optical elements) can be performed through numerous methods. The most commonly employed angle monitoring equipment are optical encoders, auto-collimators and in high accuracy applications, angle interferometry. Straightforward solutions to a relative angle measurement involve reducing the rotation to a single axis and a fixed reference frame. Even using this simplification, each of the listed monitoring solution will incur considerable cost.

The goal of this project will be to develop either a novel configuration of existing technologies or employ a novel technology to monitor the relative angle between two optical elements to allow for metrological use of a variable wavelength monochromator in X-ray measurements. NIST develops the world's Standard Reference Materials (SRMs) for the characterization of X-ray diffraction instrumentation. SRM dissemination is a core mission of NIST. In the characterization of our SRM feedstock materials, we need to determine the spectral character of our X-rays with reduced wavelength uncertainties in comparison to commercial instrumentation. A relative angle measurement apparatus for monitoring our monochromator during measurement could reduce the uncertainty of our wavelength determination. Since determining relative angles between components is a ubiquitous need within many instruments, any introduction of a novel, low cost relative angle measurement solution will have market potential.

The Phase 1 project goal is to develop a prototype relative-angle monitoring device to meet the following requirements:

- Monitor the relative angle, between two optics, co-located on a central support platform and separated approximately 25 cm to within an accuracy of <1 arc second.

- Monitor the relative angle with a frequency of > 100 measurements per second.

- Perform stable, low uncertainty angle determinations within a harsh environment. (Ozone enriched atmosphere and exposure to Bremsstrahlung radiation up to 50 keV.)

Upon a successful prototype development from Phase 1 and if sufficient funding is available, for Phase 2, the project goal is to develop a production and potentially commercialize-able angle-monitoring device to meet the following requirements:

- Monitor the relative angle, between two optics, co-located on a central support platform and separated approximately 25 cm to within an accuracy of <0.1 arc second.

- Provide monitoring within a highly compact design occupying no more than 10cm x 10cm x 5cm for each optical element (potentially co-located with rotations axes).

- Operational lifetime of > 3yrs within a harsh environment
(Ozone enriched atmosphere and exposure to Bremsstrahlung radiation up to 50 keV.)

NIST staff will be available for consultation and input if needed.

9.06.03.63-R Real-Time Intensity Monitoring of Laboratory X-ray Sources

Measurement methods using X-ray characterization are ubiquitous in materials science. World-wide, there are roughly 20,000 commercial laboratory instruments that use monochromatic X-ray sources to characterize crystalline structures. These instruments primarily use the X-ray diffraction technique to find the inter-atomic spacings within materials. X-ray Diffraction from lattice planes will cause intense X-ray reflections which are measured using rotation stages. The relative intensities of the observed X-ray lines provide both details of inter-atomic positions (crystallography) and orientation morphology of crystallites (texture). X-ray characterization techniques will often require a stable X-ray source intensity over a period of hours to for some scans days.

Direct monitoring X-ray beam stability in-situ is currently employed at synchrotron X-rays sources throughout the world. This is necessary given the highly variable nature of the intensities of X-rays from a synchrotron. The monitored incident intensity in then used to correct and compensate all diffraction measurements performed. A similar monitoring of X-ray intensities on laboratory instrumentation would provide a means of more accurate determination of a material character than currently available. In commercial laboratory X-ray systems, the minute-to-minute beam intensity variation may be smooth, but comparing X-ray intensities over a 24 hr period, one may see substantial changes in the beam intensity caused by system warm-up and stabilization. Further, the monochromatic characteristic lines of X-ray from sealed tube X-ray sources will diminish over time, and may reduce by as much as 50% over the effective lifetime of a tube.

In-situ X-ray intensity monitoring of synchrotrons is performed by either filtering off a portion of the beam as a separate monitoring experiment, or by using a large ionization chamber in the long beam paths available at synchrotron facilities. Monitoring laboratory instruments could be accomplished currently, by two known pathways; using either a highly-compact ionization chamber or by suing a very-thin, Si photodiode. For typical X-ray sealed tubes used in commercial instruments, such as Cu, Cr, and Mo characteristic line anodes, either technique should be possible. Other techniques may also be employed by the discretion of the researcher. The goal of this SBIR is to monitor monochromatic (Cu Kα) X-ray intensity stability. NIST develops the world's Standard Reference Materials (SRMs) for the characterization of X-ray diffraction instrumentation. SRM dissemination is a core mission of NIST. Our characterization of SRM feedstock materials must be in excess of measurements possible from commercial instrumentation through reduced angle uncertainties, well-characterized X-ray spectral information, and through X-ray intensity stability.

We require the development of a high-accuracy X-ray intensity monitoring solution for our NIST instrumentation. If the solution is both successful and low-cost, this type of intensity monitoring may be adopted by commercial X-ray instrument vendors to be incorporated in new instrumentation or may be retrofitted into existing systems in the field.

The Phase 1 project goal is to develop a prototype monitoring device to meet the following requirements:

- Monitor a laboratory line-focus laboratory X-ray source without obstructing the beam (approximate beam dimensions of 1mm x 12mm which represents a typical line focus coupled with a graded parabolic multilayer optic.)

- Monitor the intensity stability of monochromatic Cu* characteristic radiation from either a sealed tube and/or rotating anode laboratory source to an uncertainty of better than 3%. (*Cr, Mo, and other characteristic radiations may be addressed in Phase 2.)

• Absorb no more than 20% of the primary beam through the monitoring process. (Any more absorption would make intensity monitoring too costly for commercialization.)

Upon a successful prototype development from Phase 1and if sufficient funding is available, for Phase 2, the project goal is to develop a production and potentially commercialize-able monitoring device to meet the following requirements:

• Monitor the intensity stability of monochromatic Cu* characteristic radiation from either a sealed tube and/or rotating anode laboratory source to an uncertainty of better than 1%. (*Cr, Mo, and other characteristic radiations may be addressed in Phase 2.)

• Absorb no more than 10% of the primary beam through the monitoring process. (Any more absorption would make intensity monitoring too costly for commercialization.)

• Provide monitoring within a highly compact design occupying no more than 3cm of the X-ray beam path and containable within or adjacent to existing shutter housings.

• Operational lifetime of > 3yrs within a harsh environment (Ozone enriched atmosphere and exposure to Bremsstrahlung radiation up to 50 keV.)

NIST staff will be available for consultation and input if needed.

9.06.04.63-R Non-contact Microwave Measurement of Electrical Properties of Nanofiber Materials

Functional nanofiber materials made of carbon nanotubes, modified ceramics, and from electrically modified polymeric resins, such as polypropylene are under development for a wide range of applications. In the case of carbon nanotube fibers, applications include electromagnetic shielding and enhancing the electrical conductivity of polymers. Electrical characteristics, such as alternating current (AC) complex conductivity and dielectric permittivity, are key functional parameters of these materials. Electrical property measurement can be used for assessment of the materials quality and for controlling the manufacturing process.

NIST has developed testing methodology capable of monitoring the complex AC impedance of thin dielectric and semiconducting film at microwave frequencies. The NIST procedure involves the measurement and analysis of the scattering wave parameters (S-parameters). In this procedure the wave propagation effect in the specimen section is taken under consideration. The specimen represents a transmission line having certain electrical length. At low frequencies, where the electrical length is small, the propagation model simplifies to an expression for the input admittance of a transmission line terminated with a lumped shunt capacitance. At higher frequencies, the testing methodology accounts for the wave propagation in the specimen, and eliminates systematic uncertainties of the lumped element approximation. This approach allows for accurate determination of the specimen impedance at microwave frequencies. The results depend on the specimen lateral dimensions, residual inductance and its complex permittivity. In this testing methodology, the boundary conditions for the propagating electromagnetic wave are determined by the conducting electrodes that are in contact with the specimen.

The primary objective of the current SBIR is to extend the NIST measurement procedure to a non-contact measurement of electrical properties for nanofiber materials from reflected and transmitted microwave waves.

Milestone for Phase 1:

1. Measurement design that incorporates results from electro-magnetic propagation modeling, for a 500 micron width layer of a fabric that containing carbon nanotubes fibers.

2. Establish and demonstrate feasibility of the measurement for sensitive determination of the complex conductivity of the nanofiber materials in the frequency range of 50 MHz to 12 GHz.

Milestones for Phase 2:

1. Demonstration and delivery of a working prototype for sensitive determination of the fabric complex conductivity at frequencies of up to 12 GHz.

2. Demonstrate sensitivity and reproducibility of the measurements.

3. Utilize the new design to characterize the electrical properties a monolayer fabric, both semiconducting and dielectric.

4. Utilize the new design to determine the complex conductivity of multi-layer materials, consisting of one or two semiconducting layers separated be a dielectric layer. The frequency range is between 50 MHz and 12 GHz.

NIST Involvement:

During Phase 1 the NIST authors will be available to address questions about the previous measurement development of complex conductivity and help evaluate the proposed new non-contact measurement procedure of electrical properties for nanofiber materials from reflected and transmitted microwave waves. Test samples of the relevant nanofiber materials will be made available. During Phase 2, the NIST authors will test a measurement prototype for determination of the nanofabric complex conductivity at frequencies of up to 12 GHz.

References:
J. Obrzut, N. Noda and R. Nozaki, “Broadband Characterization of High-Dielectric Constant Films for Power-Ground Decoupling”, IEEE Trans. Instr. Meas., vol. 51, pp.829 – 832 (2002).

J. Obrzut and A. Anopchenko, “Input Impedance of a Coaxial Line Terminated With a Complex Gap Capacitance - Numerical and Experimental Analysis”, IEEE Trans. Instr. Meas., vol. 53, pp. 1197- 1201 (2004).

9.06.05.63-R Development of a MEMS Oscillatory Parallel-Plate Rheometer

A MEMS Oscillatory Parallel-Plate Rheometer has been developed and demonstrated to measure viscoelastic properties (specifically, viscosity and viscous and elastic moduli) of fluids and gels.

Growing numbers of applications including proteomics, cosmetics, and thin film coatings use novel viscoelastic materials that derive their rheological properties from micro scale structure created by the inclusion of long chain molecules, nano particles and dispersed fluids. These applications also often involve flow through confined geometries which deform the micro structure, altering the materials’ rheology and limiting their effectiveness. Characterization of these novel materials is often difficult due to the small volumes initially formulated. Therefore, “micro rheology” and thin film rheology techniques have been employed to characterize these materials. Micro rheology commonly refers to analyzing the motion of micro probe particles to measure fluid response at small length scales. This method examines a small area around the probe particle, ignoring a fluid’s micro structure. A number of methods exist to study thin films, but they rely on complex modeling of probe geometry, contact area and material properties to extract anything more than the elastic modulus of a film.

We demonstrate a MEMs parallel plate rheometer for micro rheology that confines viscoelastic materials to length scales on the order of a micrometer, but probes the entire material response to dynamic oscillatory shear. The MEMs Parallel Plate rheometer uses a 1 mm square nano positioner stage to apply a controlled sinusoidal strain, with displacement up to 15 micrometers. The instrument monitors two displacements on the MEMS platform, which measure the stress and strain in the sample. The device is suitable therefore for strain- or stress-controlled operation. Through physical modeling of the system, both storage and loss moduli can be extracted for a wide range of frequencies, from 0.5 to 500 Hz. The confinement of the fluid is set by adjusting the gap between the stage and a transparent cover plate that allows optical observation. By decreasing this gap, the increasing effects of confinement can be observed. Because the strain is applied to the entire fluid body, this device examines the effects of confinement on the entire micro structure. Furthermore, this device uses approximately 5 nL of material, which is beneficial for these types of novel experimental materials. The current NIST design and results can be found at **http://xlink.rsc.org/?doi=C005065B**. Awardees will be able to consult with the NIST technical contact about the design and most current developments.

Some developments are needed before commercialization. Primarily, real-time high resolution displacement sensing is needed to allow the device to work in stress/strain control and provide real-time results. Real-time measurement of gap sizes is also necessary to make accurate measurements. Furthermore, automated sample loading is needed for volume control and easier sample loading. Optimization of device operation including sample loading, measurement, and calibration should be developed. Optimization should include the device stiffness in and out of plane. Accordingly, NIST is soliciting proposals from small companies to meet these challenges and bring the product to market.

Phase 1 deliverable:

- Develop a full design of a linear translational parallel-plate device, including mechanical drawings, displacement sensor components, sample loading components, and specifications for in-plane and out-of-plane device stiffness, sensor resolution, control algorithms and property measurement range.

- Develop a full design of a torsional parallel-plate device, including mechanical drawings, displacement sensor components, sample loading components, and specifications for in-plane and out-of-plane device stiffness, sensor resolution, control algorithms and property measurement range.

- Development of a commercialization plan for the instrument.

Phase 2 deliverables:

- Construction and demonstration of a prototype device able to measure viscosity as low as 0.001 Pa s, and dynamic moduli as low as 1 Pa.

- Measurements from the sensors will be monitored in real-time, so that both stress- and strain-controlled measurements may be obtained.

- Temperature control. Two implementations: 5 °C to 40 °C and 30 °C to 200 °C.

- Demonstration of the device to the Technical Contact.

Reference:
Development of a MEMS based dynamic rheometer, Christopher GF, Yoo JM, Dagalakis N, Hudson SD, Migler KB, Lab Chip, 2010, DOI: 10.1039/C005065B.

9.06.06.63-R Development of Anion Exchange Resins for Chirality-Based Separation of Single Walled Carbon Nanotubes

Single-wall carbon nanotubes (SWCNTs) have many potential commercial applications. Measurement needs often require population of single-chirality tubes that current SWCNT syntheses cannot provide. Recent progress in SWCNT separation has demonstrated the possibility of using anion exchange stationary phase and specific ssDNA sequence wrapped SWNT to obtain many single chirality tubes (ref. 1). The availability of such materials should enable both metrological studies at NIST and industrial application developments around the country. However, the efficiency of the DNA-based single chirality SWNT purification process is currently limited to a very large extent by the quality of the anion exchange resin, which is developed for the separation of DNA oligonucleotides, and does not give enough resolution and recovery for the separation of DNA-wrapped SWCNTs. This call solicits research and development of new anion exchange resins that can deliver both higher recovery and higher resolution than what is currently available for the separation of DNA-wrapped SWCNTs. The research should entail development of new surface functionalization chemistry to control surface charge density, surface hydrophobicity and hydrophilicity, and reproducible batch processes for large scale production of the anion exchange resin. Major specifications are listed below.

Specifications:

1. Recovery: > 80% of the injected material is eluted from the column;

2. Resolution: capable of resolving in a single pass (9,1) and (6,5) from the CoMoCAT SWCNT starting materials.

Phase 1 milestone:
Demonstrate design concept by producing anion exchange columns that meet the above specifications;

Phase 2 milestone:
Develop reliable processes for large batch production of the new anion exchange columns, and make them commercially available.

NIST staff will be available for consultation and input if needed.

Reference:
1. Tu, X., Manohar, S., Jagota, A. & Zheng, M. DNA sequence motifs for structure-specific recognition and separation of carbon nanotubes. Nature 460, 250-253 (2009).

9.06.07.63-R Micro-cruciform Tensile Stage for XRD and SEM/EBSD

A current topic of interest in materials science and manufacturing is multiscale modeling, being able to link the atomistic deformation behavior to macroscopic deformation processes like forming a car. One crucial link for this is the meso-micro scale linking models of the internal deformation within grains of a polycrystalline material to the overall deformation of an ensemble of grains. The NIST Center for Automotive Lightweighting has been working on this topic.

A variety of complimentary characterization equipment is needed to link these scales, and having a single piece of equipment that can be shared and exchanged between these pieces of equipment are necessary. The two primary methods that are of interest is electron backscatter diffraction (EBSD) and x –ray diffraction (XRD). EBSD methods use electron diffraction to measure local orientation, local elastic stress measurements, and crystallographic texture measurements on the grain or intra-grain level. XRD methods can be used to measure crystallographic texture and local elastic stress measurements.

There are a variety of mechanical devices that can deform a material along one axis, but for many relevant to applications, multi-axis deformation is needed. One method of investigating multi-axial deformation is a cruciform geometry, where two orthogonal ‘arms’ are loaded. More details of the geometry of the cruciform sample and testing is available in a paper by Abu-Farha et al [1].

NIST solicits proposals to create a micro-cruciform stage that can be mounted in an SEM for EBSD and placed on an x-ray diffractometer. The design (phase 1) and prototype construction (phase 2) must have the following characteristics:

- Able to fit into an existing x-ray diffractometer at the NIST Center for Neutron Research. In particular, the distance from the bottom of the stage to the top of the sample must be less than 55 mm and the overall dimensions must fit within a Huber 511.51 Euler Cradle.

- Able to fit into an existing SEM in Metallurgy Division (likely a JEOL 6400) for use with EBSD. This requires the stage to be tilted at 70° relative to the electron beam line and a detector (HKL Nordlys) to be inserted approximately 10 mm from the sample. This also implies that the stage be made of appropriate materials for a vacuum of 10-6 torr.

- Sample geometries will be scaled versions of the N2.25 D6.25 samples described in [1]. Pin loading is not necessary as long as a suitable gripping method is used. The center region in the sample described in [1] will be scaled such that the diameter is 3-5 mm.

- Stage must be capable of loading a cruciform sample to loads of 30 000 N on each arm at a variable strain rate around the range of 10-3 mm/mm (quasi-static rates only). A device to provide real-time measurements and control of the plastic strain in the center region must also be provided.

• Appropriate control software will be provided such that the displacement, load, or strain may be separately controlled. In addition, each arm of the cruciform geometry must be allowed to move independently of the other.

• The load and displacement must have a “locking” or “hold” feature such that the load or displacement can be held fixed while switching the sample from the x-ray diffractometer and the SEM. This process will require temporarily severing all connectors for a period of 30 minutes, but duplicate connectors may be used during this process (i.e., connect one series of cables while disconnecting another series).

At the conclusion of Phase 1 a design with all of these features will be delivered to NIST. At the conclusion of Phase 2 a working prototype will be delivered to NIST.

NIST will also work with the awardee to test the device during development in order to provide feedback regarding its performance and provide access or measurements of the x-ray diffractometer and SEM configurations.

[1] F. Abu-Farha, L. G. Hector, M. Khraisheh. “Cruciform-Shaped Specimens for Elevated Temperature Biaxial Testing of Lightweight Materials” JOM 2009 61 p48-56.

9.06.08.68-R Orientation-Patterned Gallium Arsenide

NIST seeks development of a reliable commercial source of orientation-patterned gallium arsenide (OP GaAs) crystals, suitable for difference-frequency generation.

Periodically poled lithium niobate (PPLN) is a well-developed material that has proven to be versatile in generating a wide range of optical frequencies. However, it is only transparent below 4.5 micrometers in wavelength. OP GaAs can provide a similar functionality further into the mid- and long-wave infrared. The basic capabilities of OP GaAs have been demonstrated, but there is no commercially available product.

While OP GaAs can operate at a variety of different wavelengths, our primary interest is in difference-frequency generation between infrared radiation in the 1550 nm telecom band and infrared radiation in the 1950 nm thulium band. With such a material, difference-frequency generation of frequency combs centered at 1560 nm and 1957 nm would generate frequency combs in the so-called “fingerprint region” for precision spectroscopy.

For Phase 1, the awardee must deliver at least two OP GaAs crystals of different lengths that could be tested at NIST for conversion efficiency, bandwidth, beam quality, and other factors. These crystals would be patterned to support a 1560 nm pump and 1957 nm signal to generate output idler radiation at 7690 nm. To maintain high beam quality, the crystals should have a transverse thickness of 1 mm or higher (to avoid clipping of the beams). To reach high conversion efficiency, the crystals must be of high optical quality and have suitable anti-reflection coatings on each face. The crystal lengths should span approximately 1 mm to 5 mm to allow for meaningful exploration of bandwidths appropriate to pulsed operation.

NIST staff will be available to discuss with the awardee the testing of the conversion efficiency and other factors to determine the suitability of the material produced for its intended purpose.

If the resultant material proves suitable and if sufficient funding is available, for Phase 2, the awardee must produce and provide to NIST prototype fiber-coupled OP GaAs devices that could serve as a basis for commercial products. These would be a packaged OP GaAs device with an input fiber that supports both the 1560 nm and 1957 nm light (either cw or pulsed) and which focuses the light onto the OP GaAs waveguide with sufficient overlap to provide high-efficiency conversion of the light (to better than a factor of four below the theoretical maximum) to 7690 nm light at the free-space output.

9.07 Nanotechnology

9.07.01.68-TT 3D Tip Characterization and Surface Reconstruction Voiding

The key benefit of using critical dimension atomic force microscopes (CD-AFM) is the ability to image vertical and re-entrant surfaces such as those seen in the semiconductor industry. The instrument uses specialized tips and scanning algorithms to access feature sidewalls. To extract accurate size information from the images, the size and shape of the tip must be known.

Most of the techniques that are commercially available can only analyze 1D data. NIST has developed a method to do 3D tip characterization and surface reconstruction for re-entrant surfaces [1–3]. This provides results that better represent the imaged feature and that have a higher degree of accuracy.

One of the challenges of traceable dimensional metrology with an atomic force microscope (AFM) is the dilation of the image by the tip. Due to the finite size and shape of the AFM tip, some regions of the surface may not be accessible. This results in an image that is distorted. Techniques exist to characterize AFM tip shape and/or reconstruct some portions of the surface [1,4,5]. These methods, which use morphological and derivative techniques, have been mostly applied to non re-entrant surface data. Recent NIST work has shown techniques for reconstructing 3D re-entrant surface surfaces [2,3].

In semiconductor dimensional metrology, the CD-AFM is a widely used reference instrument. Traditionally, the parameters of interest (such as linewidth) as measured by the CD-AFM required information that could be obtained from one axis, and as such only needed a simplified tip characterization capability. Due to the increased metrology demands required to meet the specification of the international technology roadmap for semiconductors (ITRS) [6], the industry now uses a variety of parameters that are inherently two- or three-dimensional. These include contact holes, full profile, and contours needed to perform optical proximity correction. Other applications that need accurate tip characterization and image reconstruction include measurement of nanoparticles.

This solicitation is to develop and commercialize novel methods and algorithms for 3D tip characterization and surface reconstruction of re-entrant patterned features and arbitrary shapes, based on previous NIST work in tip and surface reconstruction and CD-AFM metrology [1-3,7-8].

In Phase 1 an awardee must demonstrate feasibility of extending tip-characterization techniques to two- and three-dimensional features of arbitrary shapes. This could include the use of different scanning strategies, artifacts, or analysis algorithms. The technique should be used without modifying current instruments.

If successful and if funds are available, the Phase 2 deliverables would include commercial software for 2D and 3D tip characterization and surface reconstruction for patterned features and arbitrary shapes, and tip characterizers if needed. The software should be compatible with existing AFM instruments. A copy of the software, including complete documentation of algorithms developed and source code, must be supplied to NIST for internal use.

NIST staff will be available for consultation and input if needed.

References:
[1] Villarrubia, J. S., “Algorithm for scanned probe microscope image simulation, surface reconstruction, and tip estimation,” J. Res. Natl. Inst. Stand. Technol. 102 p. 425 (1997).

[2] Qian, X., and Villarrubia, J. S., “General three dimensional image simulation and surface reconstruction in scanning probe microscopy using a dexel representation,” Ultramicroscopy 108 (1) p. 29 (2007).

[3] Tian, F., Qian, X. P., Villarrubia, J. S., “Blind estimation of general tip shape in AFM imaging,” Ultramicroscopy 109(1) p. 44 (2008).

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