NSF/DOE Partnership on Thermoelectric Devices for Vehicle Applications - 2010 Solicitation

PROGRAM SOLICITATION
NSF 10-549

National Science Foundation

Directorate for Engineering
Division of Chemical, Bioengineering, Environmental, and Transport Systems

U.S. Department of Energy, Vehicle Technologies Program

Letter of Intent Due Date(s) ***(required)*** (due by 5 p.m. proposer's local time)*:*

May 21, 2010

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

June 22, 2010

IMPORTANT INFORMATION AND REVISION NOTES

Please be advised that the *NSF Proposal & Award Policies & Procedures Guide* (PAPPG) includes revised guidelines to implement the mentoring provisions of the America COMPETES Act (ACA) (Pub. L. No. 110-69, Aug. 9, 2007.) As specified in the ACA, each proposal that requests funding to support postdoctoral researchers must include a description of the mentoring activities that will be provided for such individuals. Proposals that do not comply with this requirement will be returned without review (see the PAPP Guide Part I: *Grant Proposal Guide* Chapter II for further information about the implementation of this new requirement).

SUMMARY OF PROGRAM REQUIREMENTS

General Information

Program Title:

NSF/DOE Partnership on Thermoelectric Devices for Vehicle Applications

Synopsis of Program:

The Directorate for Engineering at the National Science Foundation has established a partnership with the U.S. Department of Energy Vehicle Technologies Program in order to address critical fundamental and applied research challenges associated with harvesting waste heat in vehicle applications. The goal of the partnership is to leverage the complementary missions of deployment and commercialization (DOE) and fundamental research and education (NSF) to address issues of national importance that impact our reliance on foreign sources of oil. The Directorate for Engineering seeks proposals with transformative ideas that will impact national needs and priorities in energy conservation and climate change, specifically as pertains to novel thermoelectric devices and systems for harvesting waste heat in vehicle applications. Proposals must meet the detailed requirements delineated in this solicitation.

Cognizant Program Officer(s):

- Theodore L. Bergman, Program Director, Thermal Transport Processes, 565, telephone: (703) 292-7494, email: tbergman@nsf.gov
- Gregory L. Rorrer, Program Director, Energy for Sustainability, 565, telephone: (703) 292-5356, email: grorrer@nsf.gov
- Arvind Atreya, Program Director, Combustion, Fire and Plasma Systems, 565, telephone: (703) 292-8695, email: aatreya@nsf.gov
- Gurpreet Singh, Group Leader, Vehicle Technologies Program/DOE, telephone: (202) 586-2333, email: gurpreet.singh@ee.doe.gov

- John Fairbanks, Technology Development Manager, Vehicle Technologies Program/DOE, telephone: (202) 586-8066, email: john.fairbanks@ee.doe.gov

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

- 47.041 --- Engineering
- 81.049 --- Office of Science Financial Assistance Program

Award Information

Anticipated Type of Award: Continuing Grant

Estimated Number of Awards: 6 to 9 Awards: Each of up to 3-years duration.

Anticipated Funding Amount: $1,000,000 to $1,500,000 $9,000,000 total, equally distributed in FY 2010, 2011, and 2012, pending availability of funds.

Eligibility Information

Organization Limit:

None Specified

PI Limit:

Principal Investigators (PIs) must be at the faculty level as determined by the submitting organization. A minimum of one PI and two co-PIs must participate. While participation from non-engineering disciplines is encouraged and may be essential for some proposals, projects should primarily contribute to engineering research.

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI: 1

The principal investigator and co-principal investigators may participate in only one proposal submitted to this solicitation. It is the responsibility of the submitting institution to insure that the PI and all co-PIs are participating in only one proposal submitted to this solicitation.

Proposal Preparation and Submission Instructions

A. Proposal Preparation Instructions

- **Letters of Intent:** Submission of Letters of Intent is required. Please see the full text of this solicitation for further information.
- **Preliminary Proposal Submission:** Not Applicable
- **Full Proposals:**
  - Full Proposals submitted via FastLane: NSF Proposal and Award Policies and Procedures Guide, Part I: Grant Proposal Guide (GPG) Guidelines apply. The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg.
  - Full Proposals submitted via Grants.gov: NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov Guidelines apply (Note: The NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide)

B. Budgetary Information

- **Cost Sharing Requirements:** Cost Sharing is not required under this solicitation.
- **Indirect Cost (F&A) Limitations:** Not Applicable
- **Other Budgetary Limitations:** Not Applicable

C. Due Dates

- **Letter of Intent Due Date(s)** ***(required)*** (due by 5 p.m. proposer's local time)***:***

  May 21, 2010

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

  June 22, 2010

Proposal Review Information Criteria

Merit Review Criteria: National Science Board approved criteria. Additional merit review considerations apply. Please see the full text of this solicitation for further information.

Award Administration Information

Award Conditions: Standard NSF award conditions apply.

Reporting Requirements: Standard NSF reporting requirements apply.

TABLE OF CONTENTS

I. INTRODUCTION

The conversion of waste heat to electricity promises to mitigate our dependence on foreign sources of energy if the conversion process is efficient, reliable, clean and cost-effective. Solid state energy conversion concepts that involve thermoelectric devices offer such promise. While the efficiency of bulk semiconductor thermoelectric devices is typically between 6 percent and 8 percent, recent developments suggest efficiency improvements to over 20 percent. When integrated into automotive exhaust systems, the potential exists for fuel savings by as much as 5 percent due to reduced engine load.

Because the National Science Foundation (NSF) and Department of Energy (DOE) have long invested in research and development of thermoelectric materials and devices, NSF and DOE have developed a jointly funded partnership to address a problem of national importance that impacts our reliance on foreign sources of oil, which at the same time addresses environmental concerns. This solicitation concerns this partnership. Specifically, proposals are solicited that are directly relevant to waste heat recovery in vehicle applications using thermoelectric devices. The awards associated with this solicitation will potentially enable the broad application of thermoelectric waste heat recovery devices at a scale commensurate with the global vehicle manufacturing enterprise. In this effort, the partnership seeks to exploit the complementary missions of (i) research and development for NSF, and (ii) deployment and commercialization for DOE to develop the critical understanding and technology improvements needed to make viable the efficient conversion of waste heat in automotive exhaust systems to electricity.

The sub-programs within NSF and DOE that will manage this partnership are the Solid State Energy Conversion Activity (SSECA) within the Vehicle Technologies Program (VTP) of DOE and the Thermal Transport Processes Program (TTP) within the Chemical, Bioengineering, Environmental and Transport Systems (CBET) Division of the Directorate for Engineering at NSF. Each of these programs includes strong components of thermoelectrics within the portfolio of projects they support. The SSECA has led the effort to realize the potential of solid state energy conversion to recover a significant fraction of the waste heat from automotive exhaust systems through the industry collaborations it supports. The TTP is a leader in supporting fundamental research and development activities in thermoelectric materials, principally at universities.

The VTP supports the mission of the DOE which is to strengthen America's energy security, environmental quality, and economic vitality. These goals are achieved through activities that enhance energy efficiency and productivity, and which commercialize clean, reliable, and affordable technologies. CBET supports the NSF mission of research and education with activities that involve the transformation and/or transport of matter and energy by chemical, thermal, or mechanical means. CBET research and education contributes significantly to the development of the workforce for major components of the U.S. economy.

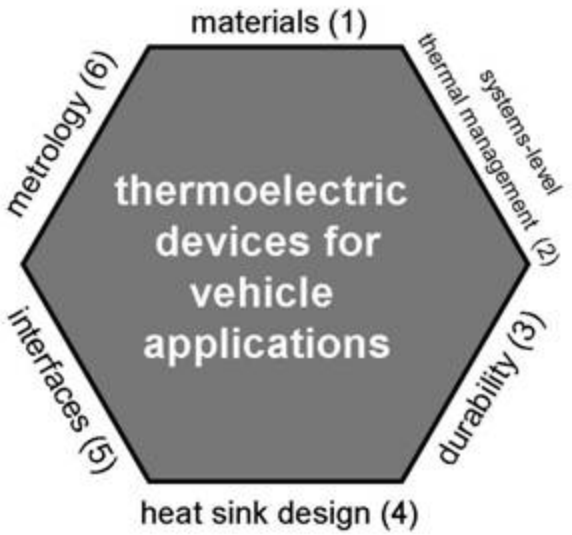
II. PROGRAM DESCRIPTION

Providing a means to economically convert the otherwise wasted heat that is contained in a vehicle's exhaust into electrical power is a key opportunity to (i) decrease fuel consumption and (ii) reduce emissions. A promising approach to take advantage of this energy harvesting opportunity is through incorporation of thermoelectric devices. Such devices might be installed within the exhaust system of a vehicle to convert the energy within the hot combustion products into high-grade electrical power. In this way thermoelectric devices could reduce the mechanical generation of electricity in any vehicle, thus allowing for smaller alternators and reduced engine load that would thereby increase fuel economy.

Thermoelectric devices are based upon materials that exhibit the so-called Seebeck effect, which is the development of electrical voltage potentials within the material that are proportional to spatial temperature differences, also within the material. Extensive fundamental research is currently underway to develop materials that are effective in this process. For the most part, current research is focused on manipulating the nanostructure of solid state thermoelectric materials in order to (i) increase the material's Seebeck coefficient, while simultaneously (ii) reducing the thermal conductivity and (iii) increasing the electrical conductivity of the material. In doing so, the efficiency by which the thermoelectric material can convert heat into electrical power is increased.

In practice, thermoelectric materials are contained within a package that constitutes a thermoelectric device. Thermoelectric devices are the focus of this solicitation.

A typical thermoelectric device consists of numerous materials, including not only the thermoelectric material but also electrical connections necessary to extract the electricity from the thermoelectric material. The multiple interfaces existing between materials and across system levels can lead to unwanted thermal and electrical contact resistances internal and external to the thermoelectric device which degrade performance. Mismatches in the thermal expansion coefficients of the various materials can also significantly reduce the durability and lifetime of thermoelectric devices, threatening the potential for broad application. A critical issue is the fact that the amount of electrical power ultimately produced by the thermoelectric device is directly related to the temperature distribution within the thermoelectric material. This distribution cannot be determined or controlled without, for example, understanding and predicting the very complex convective and radiative heat transfer processes external to the thermoelectric device. Hence, the ultimate efficiency, durability, manufacturability, and cost of thermoelectric devices hinge upon a highly-linked set of interdisciplinary challenges, as suggested in the figure below.



Six key elements of a thermoelectric waste heat recovery module for vehicle applications.

The six key elements indicated in the figure are an interdependent network which governs performance of a thermoelectric module or device. It is expected that successful proposals will address at least three of the key elements summarized below.

- Key Element 1: Materials. In addition to seeking improvements in a thermoelectric material's energy conversion efficiency or figure of merit (ZT), the cost and availability of the material itself must be considered. Materials that are rare, or are being used extensively in other alternative energy technologies that would limit their supply and availability for thermoelectric devices, show little promise for potential large-scale deployment for vehicle applications. The development of materials which are comparatively easy to manufacture, and with the potential for large scale production volumes (on the order of several thousand tons per year for automotive use), have greater promise to be integrated into thermoelectric packages.
- Key Element 2: Thermal management. The manner in which the temperature distribution within a thermoelectric device is established, and its evolution, is directly related to thermal management, specifically the process by which the hot and cold sides of the thermoelectric module are convectively and radiatively heated or cooled. System level thermal management will require bridging scales of nanometers to meters. Opportunities exist for incorporating novel thermal management techniques, including but not limited to jet impingement, effective interface materials and adhesives, mini- or microchannel cooling, and single and multiphase concepts. Efficient simulation tools and supporting experimental data for model validation are needed for an effective design.
- Key Element 3: Durability. Thermoelectric devices for automotive applications will be subjected to temperature variations and mechanical stresses (for example, vibrations) that will challenge their ability to remain operable over automotive life cycles (approximately 15 years). Robust designs are necessary to ensure long life under operational conditions.
- Key Element 4: Interfaces. Interfaces between various materials represent vital thermal and electrical links in any thermoelectric device. Furthermore, the temperature swings associated with exhaust waste heat harvesting can potentially lead to de-lamination of interfaces due to mismatches in material coefficients of thermal expansion. Research is needed to develop durable and inexpensive bonding techniques, specific to thermoelectric harvesting of vehicle waste heat.
- Key Element 5: Heat sink design. The electrical power produced by a thermoelectric device will hinge upon minimizing the thermal resistance between the device and the surroundings. Design of efficient heat sinks are critical to this process, as is reducing the thermal resistance between the thermoelectric device and heat sink. New approaches are needed to develop novel heat sink designs, specific to thermoelectric harvesting of waste heat in vehicle applications. Concepts based on multiphase fluids, finned structures, microchannels and heat pipes to name a few are envisioned, though designs which are perceived to be too difficult to manufacture or too expensive will not be competitive.
- Key Element 6: Metrology. Metrology to characterize materials and the thermal performance of thermoelectric devices is essential to establish the efficacy of any design. Use of testing and measurement concepts which are standardized (for

example, traceable to NIST standards) is important to evaluate the efficiency of proposed new thermoelectric materials (measuring ZT) at relevant temperatures. At the device or system level, it is anticipated that successful proposals will include a plan for experimental calibration and measurement of relevant performance parameters and the ability to assess accuracy, repeatability and the effect of measurement intrusiveness.

Required Elements:

To promote and accelerate thermoelectric device discovery and deployment in vehicle applications, proposals must address the following two elements:

- R1) Proposals must be submitted by teams of researchers who will simultaneously address, in a balanced manner, at least three of the six key elements indicated in the preceding discussion and figure. Funding decisions by NSF and DOE will be made, in part, by the need to include all key elements in the ultimate mix of proposals funded under this solicitation.
- R2) Proposals must address the connection of the research to deployment at a scale commensurate with the global vehicle manufacturing enterprise.

Proposals will be judged based upon the potential success of the engineering approach in achieving the goals of cost-effectiveness and large scale deployment of thermoelectric devices for exhaust waste heat recovery. Proposals that target (i) incremental improvements in energy conversion efficiency, (ii) a single discipline or traditional line, or (iii) concepts that cannot be potentially implemented at a large scale (e.g., that require chemical elements that do not exist in sufficient quantity on Earth with little possibility of integration on a large scale) will not be competitive. The synthesis of diverse disciplinary knowledge, concepts, methodologies, and technologies must be clearly described.

In preparing proposals in response to this solicitation, the text should not devote considerable space to background and motivation related to the importance of thermoelectrics for automotive waste heat recovery. These aspects are already established in this solicitation. Rather, the narrative should, within the page limit established by these guidelines, endeavor to establish the value of the proposed idea, and to discuss in sufficient detail for evaluation the approach and methods that would be brought to bear to meet project objectives.

III. AWARD INFORMATION

Anticipated Funding Level: It is anticipated that 6 or more continuing grants will be made in FY 2010. Each project team may receive support of up to a total of $500,000 per year for up to three years on a continuing basis, pending availability of funds and research progress made. It is not expected that all awards will receive the maximum amount; the size of awards will depend on the type of research program that is proposed.

IV. ELIGIBILITY INFORMATION

Organization Limit:

None Specified

PI Limit:

Principal Investigators (PIs) must be at the faculty level as determined by the submitting organization. A minimum of one PI and two co-PIs must participate. While participation from non-engineering disciplines is encouraged and may be essential for some proposals, projects should primarily contribute to engineering research.

Limit on Number of Proposals per Organization:

None Specified

Limit on Number of Proposals per PI: 1

The principal investigator and co-principal investigators may participate in only one proposal submitted to this solicitation. It is the responsibility of the submitting institution to insure that the PI and all co-PIs are participating in only one proposal submitted to this solicitation.

Additional Eligibility Info:

Proposals may be submitted by a single organization or a group of organizations consisting of a lead organization in partnership with one or more partner organizations. Only U.S. academic institutions which perform research and with degree-granting education programs in disciplines normally supported by NSF are eligible to be the lead organization. Academic institutions are defined as universities and two- and four-year colleges (including community colleges) accredited in, and having a campus located in the United States, acting on behalf of their faculty members. Principal investigators are encouraged to form synergistic collaborations with industrial researchers, government laboratories, and engineers and scientists at foreign organizations where appropriate, though no NSF funds will be provided to government labs or foreign organizations. For interaction with industry, when appropriate for the proposed research, the GOALI mechanism (Grant Opportunities for Academic Liaison with Industry NSF 09-516) may be used. Alternatively, subcontracts may be included in the award to the lead institution.

V. PROPOSAL PREPARATION AND SUBMISSION INSTRUCTIONS

A. Proposal Preparation Instructions

Letters of Intent*(required):*

A one-page Letter of Intent is required. Letters of intent are not reviewed but are used to anticipate the overall response and requirements for reviewers. The letter should be submitted via FastLane no later than the date specified in this solicitation. The subject heading of the letter should include a brief title of the proposal and the name of the lead institution. Each letter must include the following:

1. THE TITLE - Title of the proposal preceded by the words "NSF/DOE Thermoelectrics Partnership:"
2. THE TEAM - Names, departmental and university affiliation, or company affiliation and expertise of the Principal Investigator and at least two co-Principal Investigators.
3. SYNOPSIS (GOALS) - Brief description of the specific goals of the proposal (maximum of 250 words).

These letters of intent help NSF anticipate review requirements for proposals. They are not used as pre-approval mechanisms for the submission of proposals, and no feedback is provided to the submitters.

Letter of Intent Preparation Instructions:

When submitting a Letter of Intent through FastLane in response to this Program Solicitation please note the conditions outlined below:

- Sponsored Projects Office (SPO) Submission is not required when submitting Letters of Intent
- A Minimum of 2 and Maximum of 4 Other Senior Project Personnel are allowed
- Submission of multiple Letters of Intent is not allowed

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

- Full proposals submitted via FastLane: Proposals submitted in response to this program solicitation should be prepared and submitted in accordance with the general guidelines contained in the NSF Grant Proposal Guide (GPG). The complete text of the GPG is available electronically on the NSF website at: http://www.nsf.gov/publications/pub_summ.jsp?ods_key=gpg. Paper copies of the GPG may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov. Proposers are reminded to identify this program solicitation number in the program solicitation block on the NSF Cover Sheet For Proposal to the National Science Foundation. Compliance with this requirement is critical to determining the relevant proposal processing guidelines. Failure to submit this information may delay processing.

- Full proposals submitted via Grants.gov: Proposals submitted in response to this program solicitation via Grants.gov should be prepared and submitted in accordance with the NSF Grants.gov Application Guide: A Guide for the Preparation and Submission of NSF Applications via Grants.gov. The complete text of the NSF Grants.gov Application Guide is available on the Grants.gov website and on the NSF website at: (http://www.nsf.gov/publications/pub_summ.jsp?ods_key=grantsgovguide). To obtain copies of the Application Guide and Application Forms Package, click on the Apply tab on the Grants.gov site, then click on the Apply Step 1: Download a Grant Application Package and Application Instructions link and enter the funding opportunity number, (the program solicitation number without the NSF prefix) and press the Download Package button. Paper copies of the Grants.gov Application Guide also may be obtained from the NSF Publications Clearinghouse, telephone (703) 292-7827 or by e-mail from nsfpubs@nsf.gov.

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

Collaborative Proposals. All collaborative proposals submitted as separate submissions from multiple organizations must be submitted via the NSF FastLane system. Chapter II, Section D.4 of the Grant Proposal Guide provides additional information on collaborative proposals.

Full Proposal Instructions:

If there is more than one university or industry involved in a proposal, it may be submitted as a single full proposal, or as multiple collaborative proposals.

A review of proposals may include both panel and ad hoc reviews. The following exceptions and additions to the GPG apply to proposals submitted to this Program:

Cover Sheet: Select the CBET program solicitation number from the pull down list. Entries on the Cover Sheet are limited to the principal investigator and co-principal investigators. A minimum of two co-principal investigators must be listed. Additional project leaders or senior personnel should be listed on the Project Summary page and entered as senior personnel in FastLane or Grants.gov.

Title of Proposed Project: The title of the proposed project must begin with **NSF/DOE Thermoelectrics Partnership:**. The title must state clearly and succinctly the major focus of the project.

Project Summary (one-page limit): Provide the following information: (1) the title of the project, the name of the PI and the lead institution or organization, and a list of co-PIs and senior personnel along with their institutions and organization or both; (2) a succinct summary of the intellectual merit of the proposed project that states the transformative nature of the proposed research as well as the significant interdisciplinary approach to the proposed research; and (3) a succinct statement of the broader impacts of the proposed work including teaching and education plans as well as the potential impact of the research on large-scale implementation of thermoelectrics for waste heat energy conversion in vehicle applications. Proposals that do not address both intellectual merit and broader impacts in separate and clearly-marked statements within the project summary will be returned without review. Elaboration of the intellectual merit and broader impacts merit review criteria are included in VI.A NSF Merit Review Criteria.

Project Description (maximum 15 pages) must include the following subsections:

1. Results from Prior Research: Describe prior research of PI and co-PIs funded by NSF or DOE that is directly relevant to the proposed project; and
2. A table clearly indicating which of the 3 (or more) key elements of Section II. Program Description are addressed in the proposal. The table must also include the approximate percentage of the proposed effort that is dedicated to each key element listed in the table; and
3. Proposed Research: Describe specific goals of the proposed research, approaches and methodologies to attain the goals,

and the expected outcomes. The Project Description must address the required elements list in Section II. Program Description. The Project Description should end with a subsection labeled **Impact** that describes both (1) the fundamental research contributions of the proposed effort and (2) the potential for large scale implementation of the research for thermoelectric energy harvesting in vehicle applications. The relevant scale of implementation is commensurate with the global vehicle manufacturing enterprise.

References Cited. Indicate with an asterisk any cited publications that resulted from prior research funded by NSF or DOE for the PI or co-PIs.

Biographical Sketches for key personnel (PI, co-PIs, and each of the senior personnel listed on the Project Summary page). Use the standard format described in the GPG.

Current and Pending Support information must be provided for the PI and each of the co-PIs and Senior Personnel listed on the Project Summary page.

Facilities and Equipment: Provide a description of available facilities and priorities for their use, as applicable. For projects requiring additional equipment, justify the need for these resources in the context of the research proposed.

In the **Supplementary Docs** section, include the following:

1. List the key personnel involved (maximum of two pages total). Describe the qualifications of each person and how they uniquely contribute to the project. Describe how personnel are integrated to produce positive synergies;
2. Provide a detailed management plan (maximum of three pages) including means of communication and coordination, and data tracking or management within the group, management of intellectual property resulting from the project, and timeline of activities;
3. Proposals involving metrology components must include a description of how the uncertainty in, and repeatability of measured data will be determined and reported (maximum two pages).
4. For proposals that include support for post-doctoral researchers, a Post-Doc Mentoring Plan must be included as a supplementary document. Proposals that include post-doctoral researchers but do not include the Mentoring Plan as a supplementary document will be returned without review.
5. Describe a means of sharing the outcome of the research with the scientific and engineering communities including but not limited to publications, web sites, and significant data bases, etc. (maximum two pages). The description should be specific and describe what, how and when the community will have access to the results.
6. An alphabetized list of the full names and institutional affiliations of all people with conflicts of interest for all senior personnel (PI and co-PI's) and any named personnel whose salary is requested in the project budget. Conflicts to be identified are: (1) Ph.D. thesis advisors and advisees, (2) collaborators and co-authors, including post-doctoral researchers, during the preceding 48 months, and (3) any other individuals with whom, or institutions with which the investigator has financial ties (please specify type of ties).
7. Academic and industry partners must agree in advance as to how intellectual property rights will be handled. An industry-university agreement on intellectual property including publication and patent rights must be submitted prior to an award. Documentation outlining the IP agreement should be submitted with the proposal, and the signed agreement must be submitted by the date of award.

Supplementary materials may not be used to circumvent the 15-page limit on the Project Description. Information in the supplementary materials will be evaluated as part of the review process, as needed.

Pre-submission Check List:

- No principal investigator or co-principal investigator is listed as a principal investigator or co-principal investigator on any other NSF/DOE Thermoelectrics Partnership Proposal.
- The Lead PI must be at the faculty level, as determined by the submitting institution.
- The proposal has a minimum of 3 PI/Co-PIs.
- A Post Doc Mentoring Plan is included as a supplementary document, if applicable.
- Each annual budget does not exceed $500,000, and the duration of the research does not exceed 3 years.

B. Budgetary Information

Cost Sharing: Cost sharing is not required under this solicitation.

C. Due Dates

- **Letter of Intent Due Date(s)** ***(required)*** (due by 5 p.m. proposer's local time)***:***

  May 21, 2010

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

  June 22, 2010

D. FastLane / Grants.gov Requirements

- **For Proposals Submitted Via FastLane:**

  Detailed technical instructions regarding the technical aspects of preparation and submission via FastLane are available at: https://www.fastlane.nsf.gov/a1/newstan.htm. For FastLane user support, call the FastLane Help Desk at 1-800-673-6188 or e-mail fastlane@nsf.gov. The FastLane Help Desk answers general technical questions related to the use of the FastLane

system. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this funding opportunity.

Submission of Electronically Signed Cover Sheets. The Authorized Organizational Representative (AOR) must electronically sign the proposal Cover Sheet to submit the required proposal certifications (see Chapter II, Section C of the Grant Proposal Guide for a listing of the certifications). The AOR must provide the required electronic certifications within five working days following the electronic submission of the proposal. Further instructions regarding this process are available on the FastLane Website at: https://www.fastlane.nsf.gov/fastlane.jsp.

- **For Proposals Submitted Via Grants.gov:**

Before using Grants.gov for the first time, each organization must register to create an institutional profile. Once registered, the applicant's organization can then apply for any federal grant on the Grants.gov website. The Grants.gov's Grant Community User Guide is a comprehensive reference document that provides technical information about Grants.gov. Proposers can download the User Guide as a Microsoft Word document or as a PDF document. The Grants.gov User Guide is available at: http://www.grants.gov/CustomerSupport. In addition, the NSF Grants.gov Application Guide provides additional technical guidance regarding preparation of proposals via Grants.gov. For Grants.gov user support, contact the Grants.gov Contact Center at 1-800-518-4726 or by email: support@grants.gov. The Grants.gov Contact Center answers general technical questions related to the use of Grants.gov. Specific questions related to this program solicitation should be referred to the NSF program staff contact(s) listed in Section VIII of this solicitation.

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

VI. NSF PROPOSAL PROCESSING AND REVIEW PROCEDURES

Proposals received by NSF are assigned to the appropriate NSF program where they will be reviewed if they meet NSF proposal preparation requirements. All proposals are carefully reviewed by a scientist, engineer, or educator serving as an NSF Program Officer, and usually by three to ten other persons outside NSF who are experts in the particular fields represented by the proposal. These reviewers are selected by Program Officers charged with the oversight of the review process. Proposers are invited to suggest names of persons they believe are especially well qualified to review the proposal and/or persons they would prefer not review the proposal. These suggestions may serve as one source in the reviewer selection process at the Program Officer's discretion. Submission of such names, however, is optional. Care is taken to ensure that reviewers have no conflicts of interest with the proposal.

A. NSF Merit Review Criteria

All NSF proposals are evaluated through use of the two National Science Board (NSB)-approved merit review criteria: intellectual merit and the broader impacts of the proposed effort. In some instances, however, NSF will employ additional criteria as required to highlight the specific objectives of certain programs and activities.

The two NSB-approved merit review criteria are listed below. The criteria include considerations that help define them. These considerations are suggestions and not all will apply to any given proposal. While proposers must address both merit review criteria, reviewers will be asked to address only those considerations that are relevant to the proposal being considered and for which the reviewer is qualified to make judgements.

What is the intellectual merit of the proposed activity?
How important is the proposed activity to advancing knowledge and understanding within its own field or across different fields? How well qualified is the proposer (individual or team) to conduct the project? (If appropriate, the reviewer will comment on the quality of the prior work.) To what extent does the proposed activity suggest and explore creative, original, or potentially transformative concepts? How well conceived and organized is the proposed activity? Is there sufficient access to resources?

What are the broader impacts of the proposed activity?
How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)? To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks, and partnerships? Will the results be disseminated broadly to enhance scientific and technological understanding? What may be the benefits of the proposed activity to society?

Examples illustrating activities likely to demonstrate broader impacts are available electronically on the NSF website at: http://www.nsf.gov/pubs/gpg/broaderimpacts.pdf.

Mentoring activities provided to postdoctoral researchers supported on the project, as described in a one-page supplementary document, will be evaluated under the Broader Impacts criterion.

NSF staff also will give careful consideration to the following in making funding decisions:

Integration of Research and Education
One of the principal strategies in support of NSF's goals is to foster integration of research and education through the programs, projects, and activities it supports at academic and research institutions. These institutions provide abundant opportunities where individuals may concurrently assume responsibilities as researchers, educators, and students and where all can engage in joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

Integrating Diversity into NSF Programs, Projects, and Activities
Broadening opportunities and enabling the participation of all citizens -- women and men, underrepresented minorities, and persons with disabilities -- is essential to the health and vitality of science and engineering. NSF is committed to this principle of diversity and deems it central to the programs, projects, and activities it considers and supports.

Additional Review Criteria:

The objective of this solicitation is focused. Specifically, proposed research must be directly relevant to waste heat recovery in vehicle applications using thermoelectric devices. It is expected that PIs will generate proposals that will potentially enable the broad application of thermoelectric waste heat recovery devices at a scale commensurate with the global vehicle manufacturing enterprise. Proposals that put forward approaches that cannot be potentially implemented at a large scale will not be competitive.

Proposals must be submitted by teams of researchers who will simultaneously address, in a balanced manner, at least three of the six key elements identified in the program description. Please see the full text of this solicitation for further information.

B. Review and Selection Process

Proposals submitted in response to this program solicitation will be reviewed by Ad hoc Review and/or Panel Review.

Reviewers will be asked to formulate a recommendation to either support or decline each proposal. The Program Officer assigned to manage the proposal's review will consider the advice of reviewers and will formulate a recommendation.

After scientific, technical and programmatic review and consideration of appropriate factors, the NSF Program Officer recommends to the cognizant Division Director whether the proposal should be declined or recommended for award. NSF is striving to be able to tell applicants whether their proposals have been declined or recommended for funding within six months. The time interval begins on the deadline or target date, or receipt date, whichever is later. The interval ends when the Division Director accepts the Program Officer's recommendation.

A summary rating and accompanying narrative will be completed and submitted by each reviewer. In all cases, reviews are treated as confidential documents. Verbatim copies of reviews, excluding the names of the reviewers, are sent to the Principal Investigator/Project Director by the Program Officer. In addition, the proposer will receive an explanation of the decision to award or decline funding.

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

VII. AWARD ADMINISTRATION INFORMATION

A. Notification of the Award

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

B. Award Conditions

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

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

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

C. Reporting Requirements

For all multi-year grants (including both standard and continuing grants), the Principal Investigator must submit an annual project report to the cognizant Program Officer at least 90 days before the end of the current budget period. (Some programs or awards require more frequent project reports). Within 90 days after expiration of a grant, the PI also is required to submit a final project report, and a project outcomes report for the general public.

Failure to provide the required annual or final project reports, or the project outcomes report will delay NSF review and processing of any future funding increments as well as any pending proposals for that PI. PIs should examine the formats of the required reports

in advance to assure availability of required data.

PIs are required to use NSF's electronic project-reporting system, available through FastLane, for preparation and submission of annual and final project reports. Such reports provide information on activities and findings, project participants (individual and organizational) publications; and, other specific products and contributions. PIs will not be required to re-enter information previously provided, either with a proposal or in earlier updates using the electronic system. Submission of the report via FastLane constitutes certification by the PI that the contents of the report are accurate and complete. The project outcomes report must be prepared and submitted using Research.gov. This report serves as a brief summary, prepared specifically for the public, of the nature and outcomes of the project. This report will be posted on the NSF website exactly as it is submitted by the PI.

VIII. AGENCY CONTACTS

General inquiries regarding this program should be made to:

- Theodore L. Bergman, Program Director, Thermal Transport Processes, 565, telephone: (703) 292-7494, email: tbergman@nsf.gov
- Gregory L. Rorrer, Program Director, Energy for Sustainability, 565, telephone: (703) 292-5356, email: grorrer@nsf.gov
- Arvind Atreya, Program Director, Combustion, Fire and Plasma Systems, 565, telephone: (703) 292-8695, email: aatreya@nsf.gov
- Gurpreet Singh, Group Leader, Vehicle Technologies Program/DOE, telephone: (202) 586-2333, email: gurpreet.singh@ee.doe.gov
- John Fairbanks, Technology Development Manager, Vehicle Technologies Program/DOE, telephone: (202) 586-8066, email: john.fairbanks@ee.doe.gov

For questions related to the use of FastLane, contact:

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

For questions relating to Grants.gov contact:

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

IX. OTHER INFORMATION

The NSF Website provides the most comprehensive source of information on NSF Directorates (including contact information), programs and funding opportunities. Use of this Website by potential proposers is strongly encouraged. In addition, National Science Foundation Update is a free e-mail subscription service designed to keep potential proposers and other interested parties apprised of new NSF funding opportunities and publications, important changes in proposal and award policies and procedures, and upcoming NSF Regional Grants Conferences. Subscribers are informed through e-mail when new publications are issued that match their identified interests. Users can subscribe to this service by clicking the "Get NSF Updates by Email" link on the NSF web site.

Grants.gov provides an additional electronic capability to search for Federal government-wide grant opportunities. NSF funding opportunities may be accessed via this new mechanism. Further information on Grants.gov may be obtained at http://www.grants.gov.

ABOUT THE NATIONAL SCIENCE FOUNDATION

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

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

NSF receives approximately 40,000 proposals each year for research, education and training projects, of which approximately 11,000 are funded. In addition, the Foundation receives several thousand applications for graduate and postdoctoral fellowships. The agency operates no laboratories itself but does support National Research Centers, user facilities, certain oceanographic vessels and Antarctic research stations. The Foundation also supports cooperative research between universities and industry, US participation in international scientific and engineering efforts, and educational activities at every academic level.

Facilitation Awards for Scientists and Engineers with Disabilities provide funding for special assistance or equipment to enable persons with disabilities to work on NSF-supported projects. See Grant Proposal Guide Chapter II, Section D.2 for instructions regarding preparation of these types of proposals.

The National Science Foundation has Telephonic Device for the Deaf (TDD) and Federal Information Relay Service (FIRS) capabilities that enable individuals with hearing impairments to communicate with the Foundation about NSF programs, employment

or general information. TDD may be accessed at (703) 292-5090 and (800) 281-8749, FIRS at (800) 877-8339.

The National Science Foundation Information Center may be reached at (703) 292-5111.

The National Science Foundation promotes and advances scientific progress in the United States by competitively awarding grants and cooperative agreements for research and education in the sciences, mathematics, and engineering.

To get the latest information about program deadlines, to download copies of NSF publications, and to access abstracts of awards, visit the NSF Website at http://www.nsf.gov

- **Location:** 4201 Wilson Blvd. Arlington, VA 22230
- **For General Information** (NSF Information Center)**:** (703) 292-5111
- **TDD (for the hearing-impaired):** (703) 292-5090
- **To Order Publications or Forms:**

  Send an e-mail to: nsfpubs@nsf.gov

  or telephone: (703) 292-7827
- **To Locate NSF Employees:** (703) 292-5111

PRIVACY ACT AND PUBLIC BURDEN STATEMENTS

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

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

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Reports Clearance Officer
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